CANCER TREATMENT USING HUMANIZED ANTIBODIES THAT BIND TO EPHB4

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ABSTRACT
In certain embodiments, this application provides humanized antibodies that bind to the EphB4 protein as well as uses of the antibodies for therapeutic purposes.

8 Claims, 6 Drawing Sheets
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Figure 1

1 melrvilcwa slaalaetel lntkletadl kwvtfpqvdg qweelseglde eqhsvrtve
61 cdvqrapgqa hvrlrgwvpv rgavhvyat1 rftmlecsl pragrocket ftvfyyesda
121 dtaataltqaw menpyikvdtt vaaehltkr prgaatgkvn vktirlpplcs kagfylafqd
181 qgacmalsl hlffykecaqlv tvinltpfpet vprerlvvpva gscyvdavpa ppgpspslycr
241 edgqwaeqpfe tcgscapgfee aaeongkkra caqgfkplks ggegcqcpa sarhtigsa
301 vcqcrvgvyr artdprarpc tpqapspsrv vsringsshh lewsaplesg gredtyalr
361 crecrpggsc apcggdltdf pprrdlvepwp vvrgrlrdpgf tytfesvltaln gvsllatgvp
421 pfepnvvttdd revppavsdv rvcrrpaspp slawajrprg sgauidyevk yhekgaepp
481 svrflktsen raerlrlkgrg asylvqvrar seagygpfgq ehhsqtgilde segwrgalal
541 iagtavvyvvr lvvvivvav lclrkqnsgr eaeysdkhgq ylighgtkvy idpftyrdepn
601 eavrefakel dsvqykeiev igagefgvec rgrlikgkk eescvktikkg ggyterqrrre
661 fseasimqq fehnpnirle gyyfnspymv iltefnemg ia slfrindq gftvqigvml
721 lrqisagmry laemvsvrhd laarimvms nlqcvksdftg slrsfeens dntyssllg
781 kipirrqtape aiafrkftsa sdawyqyivm wemysfgerp ywdmsnqdvi nauedyrilp
841 ppdpclt1sh qlmlfncwqkd rrnprrwpcg vsaialkmiirn paslknivre nqgashplld
901 qrrphysagf svgewlarik mgryeesfaa agfgsfelvs qisaedllri gvtlaghqkk
961 ilasvqhmkx qakpgtpggg gsgapqy
### Sandwich ELISA: 47 Variants

#### Figure 3A

![Sandwich ELISA: 47 Variants Graph](image)

<table>
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<tr>
<th>Chimerec 47</th>
<th>3/7</th>
<th>3/8</th>
<th>4/7</th>
<th>4/8</th>
<th>Chimerec 47</th>
</tr>
</thead>
<tbody>
<tr>
<td>50% Binding (ng/ml)</td>
<td>2</td>
<td>1.8</td>
<td>2</td>
<td>2.8</td>
<td>3.3</td>
</tr>
</tbody>
</table>

#### Figure 3B

![Table of 50% Binding Values](image)
Figure 4A

Sandwich ELISA: 131 Variants

Figure 4B

<table>
<thead>
<tr>
<th></th>
<th>50% Binding (ng/ml)</th>
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<tr>
<td>Chimeric 131</td>
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<tr>
<td>14/18</td>
<td>8</td>
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<td>14/17</td>
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<tr>
<td>13/17</td>
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<tr>
<td>13/18</td>
<td>11</td>
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</table>
CANCER TREATMENT USING HUMANIZED ANTIBODIES THAT BIND TO EPHB4

RELATED APPLICATIONS

This application claims the benefit of priority of U.S. Provisional Application No. 60/964,496 filed Aug. 13, 2007, the entire teachings of which are incorporated herein by reference in their entirety.

BACKGROUND OF THE INVENTION

Angiogenesis, the development of new blood vessels from the endothelium of a preexisting vasculature, is a critical process in the growth, progression, and metastasis of solid tumors within the host. During physiologically normal angiogenesis, the autocrine, paracrine, and amphiocrine interactions of the vascular endothelium with its surrounding stromal components are tightly regulated both spatially and temporally. Additionally, the levels and activities of proangiogenic and angiostatic cytokines and growth factors are maintained in balance. In contrast, the pathological angiogenesis necessary for active tumor growth is sustained and persistent, representing a dysregulation of the normal angiogenic system. Solid and hematopoietic tumor types are particularly associated with a high level of abnormal angiogenesis.

It is generally thought that the development of tumor consists of sequential, and interrelated steps that lead to the generation of an autonomous clone with aggressive growth potential. These steps include sustained growth and unlimited self-renewal. Cell populations in a tumor are generally characterized by growth signal self-sufficiency, decreased sensitivity to growth suppressive signals, and resistance to apoptosis. Genetic or cytogenetic events that initiate aberrant growth sustain cells in a prolonged “ready” state by preventing apoptosis.

SUMMARY OF THE INVENTION

This application provides, inter alia, antibodies, e.g., modified antibodies, or antigen-binding fragments thereof that bind to the extracellular domain of EphB4. The modified anti-EphB4 antibodies, or antigen-binding fragments thereof are less immunogenic compared to their unmodified parent antibodies in a given species, e.g., a human. The antibodies and antigen binding fragments are useful in therapeutic treatments for affecting EphB4 function in order to inhibit angiogenesis and tumor growth.

In one embodiment, the application provides a deimmunized antibody or antigen binding fragment thereof that binds to the extracellular domain of EphB4. The modified anti-EphB4 antibodies, or antigen-binding fragments thereof are less immunogenic compared to their unmodified parent antibodies in a given species, e.g., a human. The antibodies and antigen binding fragments are useful in therapeutic treatments for affecting EphB4 function in order to inhibit angiogenesis and tumor growth.

In one embodiment, the deimmunized antibody or antigen binding fragment thereof has one or more complementarity determining regions (CDRs) from a nonhuman or parent antibody that binds the extracellular domain of EphB4. In one embodiment, between 1-5 substitutions are present in the complementarity determining regions (CDRs).

In one embodiment, one or more substitutions reduces the number of T-cell epitopes in the deimmunized antibody or antigen binding fragment thereof as compared to the nonhuman or parent antibody. In one embodiment, one or more substitutions reduces the number of B-cell epitopes in the deimmunized antibody or antigen binding fragment thereof as compared to the nonhuman or parent antibody. In one embodiment, one or more substitutions reduces the number of T-cell epitopes in the deimmunized antibody or antigen binding fragment thereof as compared to the nonhuman or parent antibody. In one embodiment, one or more substitutions reduces the number of B-cell epitopes in the deimmunized antibody or antigen binding fragment thereof as compared to the nonhuman or parent antibody.

In one embodiment, the heavy chain variable region of the deimmunized antibody or antigen binding fragment thereof has 20 or fewer amino acid substitutions in comparison to a nonhuman or parent antibody that binds the extracellular domain of EphB4. In another embodiment, the heavy chain variable region of the deimmunized antibody or antigen binding fragment thereof has 19 or fewer, 18 or fewer, 17 or fewer, 16 or fewer, 15 or fewer, 14 or fewer, 13 or fewer, 12 or fewer, 11 or fewer, 10 or fewer, 9 or fewer, 8 or fewer, or 7 or fewer amino acid substitutions in comparison to a nonhuman or parent antibody.

In one embodiment, the heavy chain variable region has at least 2, at least 3, at least 4, at least 5, at least 6, at least 7, at least 8, at least 9, at least 10, at least 11, at least 12, or at least 13 amino acid substitutions in comparison to a nonhuman or parent antibody.

In one embodiment, the light chain variable region of the deimmunized antibody or antigen binding fragment thereof has 20 or fewer amino acid substitutions in comparison to a nonhuman or parent antibody that binds the extracellular domain of EphB4. In another embodiment, the light chain variable region of the deimmunized antibody or antigen binding fragment thereof has 19 or fewer, 18 or fewer, 17 or fewer, 16 or fewer, 15 or fewer, 14 or fewer, 13 or fewer, 12 or fewer, 11 or fewer, 10 or fewer, 9 or fewer, 8 or fewer, or 7 or fewer amino acid substitutions in comparison to a nonhuman or parent antibody that binds the extracellular domain of EphB4.

In one embodiment, the light chain variable region has at least 2, at least 3, at least 4, at least 5, at least 6, at least 7, at least 8, at least 9, at least 10, at least 11, at least 12, or at least 13 amino acid substitutions in comparison to a nonhuman or parent antibody.

In one embodiment, the deimmunized antibody or antigen binding fragment thereof binds to the extracellular domain of EphB4 with a similar or greater binding affinity than mouse monoclonal antibody #131, ATCC deposit number PTA-6214.

In one embodiment, the substitutions in the deimmunized antibody or antigen binding fragment thereof result in an increase in the sequence identity between the framework region of the antibody or antigen binding fragment and a human germline gene sequence that is homologous to said framework region.

In one embodiment, the deimmunized antibody or antigen binding fragment thereof inhibits the formation of tubes by cultured endothelial cells. In another embodiment, the deimmunized antibody or antigen binding fragment thereof inhibits the vascularization of a tissue in vivo. In another embodiment, the deimmunized antibody or antigen binding fragment thereof decreases the growth of a human tumor xenograft in a mouse. In a further embodiment, the deimmunized antibody or antigen binding fragment thereof inhibits the vascularization of a tissue implanted in the cornea of an animal or the vascularization of a Matrigel tissue plug implanted in an animal. In one embodiment, the deimmunized antibody or antigen binding fragment thereof promotes apoptosis.

In some embodiments, the effector function of the deimmunized antibody or antigen binding fragment thereof is altered. In another embodiment, the effector function of the deimmunized antibody or antigen binding fragment thereof is increased. In another embodiment, the effector function of the deimmunized antibody or antigen binding fragment thereof is increased.
deimmunized antibody or antigen binding fragment thereof is decreased. In some embodiments, the deimmunized antibody or antigen binding fragment comprises a heavy chain constant region. In some embodiments, the N-glycosylation in the Fc region is removed. In some embodiments, the Fc region comprises a mutation within the N-glycosylation recognition sequence, whereby the Fc region of the antibody or polypeptide is not N-glycosylated. In some embodiments, the Fc region is PEGylated. In some embodiments, the heavy chain constant region is a human heavy chain IgG2a constant region containing the following residues: serine at positions 330 and 331. In some embodiments, the heavy chain constant region is a human heavy chain IgG4 comprising the following mutations: proline at position 233, valine at position 234, and alanine at position 235. These amino acid positions are based on Kabat numbering.

In one embodiment, the deimmunized antibody or antigen binding fragment thereof inhibits EphB4 dimerization or multimerization. In one embodiment, the deimmunized antibody or antigen binding fragment thereof inhibits the EphrinB2 stimulated autophosphorylation of EphB4. In one embodiment, the deimmunized antibody or antigen binding fragment thereof stimulates EphB4 kinase activity.

In one embodiment, the deimmunized antibody or antigen binding fragment thereof binds to the first fibronectin-like domain of EphB4. In one embodiment, the deimmunized antibody or antigen binding fragment thereof binds to the second fibronectin-like domain of EphB4.

In one embodiment, the deimmunized antibody or antigen binding fragment thereof is conjugated to a cytotoxic agent. In one embodiment, the cytotoxic agent is selected from the group consisting of a radioactive agent, a molecule of plant, fungal or bacterial origin, such as for example saporin, a biologica protein, vinblastine, 4-desacetylvinblastine, vincristine, leurosidine, and vindesine. In certain embodiments, the antibody or antigen binding fragment thereof is conjugated to a cytotoxic agent through a stable linker which releases the cytotoxic agent inside cancer cells.

In one embodiment, the variable region of the antibody or antigen binding fragment has between 2 to 20 amino acid substitutions in comparison to a nonhuman or parent antibody that binds the extracellular domain, wherein said nonhuman or parent antibody also provides one or more CDRs in the deimmunized antibody or antigen binding fragment thereof. In a further embodiment, the deimmunized antibody or antigen binding fragment thereof includes a heavy chain variable region and a light chain variable region, wherein each variable region has between 2 to 20 amino acid substitutions in comparison to a nonhuman or parent antibody that binds the extracellular domain of EphB4, and the deimmunized antibody or antigen binding fragment thereof has one or more complementarity determining regions (CDRs) from said nonhuman or parent antibody. In a further embodiment, the deimmunized antibody or antigen binding fragment thereof is less immunogenic in a human subject than said nonhuman or parent antibody.

In one embodiment, the nonhuman or parent antibody is mouse monoclonal #47 or mouse monoclonal #131; ATCC Deposit Designation Nos. PTA-11338 and PTA-6214, respectively. In a further embodiment, one or more of the substitutions in the heavy chain variable region occurs at an amino acid position selected from the group consisting of positions 5, 12, 40, 66, 75, and 83 according to the Kabat numbering system. In a further embodiment, one or more substitutions in the heavy chain variable region is selected from the group consisting of valine at position 5, lysine at position 12, alanine at position 40, arginine at position 66, threonine at position 75, and arginine at position 83, said positions according to the Kabat numbering system.

In a further embodiment, one or more substitutions in the light chain variable region occurs at an amino acid position selected from the group consisting of positions 45, 74, and 78 according to the Kabat numbering system. In another embodiment, one or more substitutions in the light chain variable region is selected from the group consisting of lysine at position 45, threonine at position 74, and glutamine at position 100, according to the Kabat numbering system.

In one embodiment, the heavy chain variable region includes a) an FR1 selected from the group consisting of amino acids 1-30 of SEQ ID NO:1, SEQ ID NO:3, SEQ ID NO:4, SEQ ID NO:10, SEQ ID NO:11, and SEQ ID NO:13; b) an FR2 selected from the group consisting of amino acids 36-49 of SEQ ID NO:1, SEQ ID NO:3, SEQ ID NO:5, SEQ ID NO:10, and SEQ ID NO:13; c) an FR3 selected from the group consisting of amino acids 67-98 of SEQ ID NO:1, SEQ ID NO:2, SEQ ID NO:3, SEQ ID NO:4, SEQ ID NO:5, SEQ ID NO:10, SEQ ID NO:11, SEQ ID NO:12, and SEQ ID NO:14; and d) an FR4 selected from the group consisting of amino acids 113-123 of SEQ ID NO:1 and SEQ ID NO:10.

In one embodiment, the light chain variable region includes a) an FR1 selected from the group consisting of amino acids 1-23 of SEQ ID NO:6, SEQ ID NO:15, and SEQ ID NO:16; b) an FR2 selected from the group consisting of amino acids 35-49 of SEQ ID NO:6, SEQ ID NO:7, SEQ ID NO:9, SEQ ID NO:15, and SEQ ID NO:18; c) an FR3 selected from the group consisting of amino acids 57-88 of SEQ ID NO:6, SEQ ID NO:7, SEQ ID NO:8, SEQ ID NO:15, and SEQ ID NO:17; and d) an FR4 selected from the group consisting of amino acids 98-107 of SEQ ID NO:6 and SEQ ID NO:15.

In one embodiment, the heavy chain variable region of the deimmunized antibody or antigen binding fragment thereof includes a CDR1 including SEQ ID NO:19, a CDR2 including SEQ ID NO:20, and a CDR3 including SEQ ID NO:21; and wherein the light chain includes a CDR1 including SEQ ID NO:22, a CDR2 including SEQ ID NO:23, and a CDR3 including SEQ ID NO:24. In a further embodiment, the deimmunized antibody or antigen binding fragment thereof is less immunogenic in a human subject than mouse monoclonal antibody #47. In a further embodiment, the deimmunized antibody or antigen binding fragment thereof binds the extracellular domain of EphB4 with a binding affinity which is at least 80%, at least 90%, or at least 100% of the binding affinity of mouse monoclonal antibody #47 binding to the extracellular domain of EphB4.

In a further embodiment, the deimmunized antibody or antigen binding fragment thereof inhibits binding of EphB4 to the extracellular portion of EphrinB2. In a further embodiment, the deimmunized antibody or antigen binding fragment thereof inhibits EphB4 dimerization or multimerization. In a further embodiment, the deimmunized antibody or antigen binding fragment thereof inhibits the EphrinB2 stimulated autophosphorylation of EphB4. In a further embodiment, the deimmunized antibody or antigen binding fragment thereof stimulates EphB4 kinase activity. In a further embodiment, the deimmunized antibody or antigen binding fragment thereof binds to the first fibronectin-like domain of EphB4. In a further embodiment, the binds to the second fibronectin-like domain of EphB4.

In a further embodiment, the deimmunized antibody or antigen binding fragment thereof is conjugated to a cytotoxic agent. In a further embodiment, the cytotoxic agent is selected from the group consisting of a radioactive agent, a molecule of plant, fungal or bacterial origin such as saporin, a biologica-
cal protein, vinblastine, 4-desacetylvinblastine, vinercistine, leurosidine, and vindesine. In certain embodiments, the antibody or antigen binding fragment thereof is conjugated to a cytotoxic agent through a stable linker which releases the cytotoxic agent inside cancer cells.

In a further embodiment, the deimmunized antibody or antigen binding fragment thereof inhibits the formation of tubes by cultured endothelial cells. In a further embodiment, the deimmunized antibody or antigen binding fragment thereof inhibits the vascularization of a tissue in vivo. In a further embodiment, the deimmunized antibody or antigen binding fragment thereof decreases the growth of a human tumor xenograft in a mouse. In a further embodiment, the deimmunized antibody or antigen binding fragment thereof inhibits the vascularization of tissue implanted in the cornea of an animal or the vascularization of a Matrigel tissue plug implanted in an animal. In a further embodiment, the deimmunized antibody or antigen binding fragment thereof promotes apoptosis.

In some embodiments, the effector function of the deimmunized antibody or antigen binding fragment thereof is altered. In another embodiment, the effector function of the deimmunized antibody or antigen binding fragment thereof is increased. In another embodiment, the effector function of the deimmunized antibody or antigen binding fragment thereof is decreased. In some embodiments, the deimmunized antibody or antigen binding fragment comprises a heavy chain constant region. In some embodiments, the N-glycosylation in the Fe region is removed.

In a further embodiment, the heavy chain variable region of the antibody or antigen binding fragment thereof includes a) an FR1 selected from the group consisting of amino acids 1-30 of SEQ ID NO:1, SEQ ID NO:3, and SEQ ID NO:4; b) an FR2 selected from the group consisting of amino acids 36-49 of SEQ ID NO:1, SEQ ID NO:3, and SEQ ID NO:5; c) an FR3 selected from the group consisting of amino acids 67-98 of SEQ ID NO:1, SEQ ID NO:2, SEQ ID NO:3, SEQ ID NO:4, and SEQ ID NO:5; and d) an FR4 consisting of amino acids 113-123 of SEQ ID NO:1; and the light chain variable region includes a) an FR1 consisting of amino acids 1-23 of SEQ ID NO:6; b) an FR2 selected from the group consisting of amino acids 35-49 of SEQ ID NO:6, SEQ ID NO:7, and SEQ ID NO:9; c) an FR3 selected from the group consisting of amino acids 57-88 of SEQ ID NO:6, SEQ ID NO:7, and SEQ ID NO:8; and d) an FR4 consisting of amino acids 98-107 of SEQ ID NO:6.

In a further embodiment, the heavy chain variable region of the antibody or antigen binding fragment includes an amino acid sequence selected from the group consisting of: a) SEQ ID NO:1; b) SEQ ID NO:2; c) SEQ ID NO:3; d) SEQ ID NO:4; and e) SEQ ID NO:5.

In a further embodiment, the light chain variable region of the antibody or antigen binding fragment includes an amino acid sequence selected from the group consisting of: a) SEQ ID NO:6; b) SEQ ID NO:7; c) SEQ ID NO:8; and d) SEQ ID NO:9.

In a further embodiment, the heavy chain variable region of the antibody or antigen binding fragment includes an amino acid sequence selected from the group consisting of: a) SEQ ID NO:1; b) SEQ ID NO:2; c) SEQ ID NO:3, d) SEQ ID NO:4; and e) SEQ ID NO:5; and the light chain variable region of the antibody or antigen binding fragment includes an amino acid sequence selected from the group consisting of: a) SEQ ID NO:6; b) SEQ ID NO:7; c) SEQ ID NO:8; and d) SEQ ID NO:9.

In a further embodiment, the heavy chain variable region of the antibody or antigen binding fragment includes the amino acid sequence of SEQ ID NO:3, and the light chain variable region includes an amino acid sequence selected from the group consisting of: a) SEQ ID NO: 7 and b) SEQ ID NO:8.

In a further embodiment, the heavy chain variable region includes the amino acid sequence of SEQ ID NO: 4, and the light chain variable region includes an amino acid sequence selected from the group consisting of: a) SEQ ID NO: 7 and b) SEQ ID NO:8.

In a further embodiment, the heavy chain variable region includes the amino acid sequence of SEQ ID NO:3, and the light chain variable region includes the amino acid sequence of SEQ ID NO:8.

In one embodiment, the heavy chain variable region of the antibody or antigen binding fragment includes a CDR1 including SEQ ID NO:25, a CDR2 including SEQ ID NO:26, and a CDR3 including SEQ ID NO:27; and the light chain variable region includes a CDR1 and a CDR2 including SEQ ID NO:29, and a CDR3 including SEQ ID NO:30. In a further embodiment, the deimmunized antibody or antigen binding fragment thereof is less immunogenic in a human subject than mouse monoclonal antibody #131.

In a further embodiment, the deimmunized antibody or antigen binding fragment thereof binds the extracellular domain of EphB4 with a binding affinity which is at least 80%, at least 90%, or at least 100% of the binding affinity of mouse monoclonal antibody #131 binding to the extracellular domain of EphB4.

In a further embodiment, the deimmunized antibody or antigen binding fragment thereof inhibits binding of EphB4 to the extracellular portion of EphrinB2. In a further embodiment, the deimmunized antibody or antigen binding fragment thereof inhibits EphB4 dimerization or multimerization. In a further embodiment, the deimmunized antibody or antigen binding fragment thereof inhibits the EphrinB2 stimulated autophosphorylation of EphB4. In a further embodiment, the deimmunized antibody or antigen binding fragment thereof stimulates EphB4 kinase activity. In a further embodiment, the deimmunized antibody or antigen binding fragment thereof binds to the first fibronectin-like domain of EphB4. In a further embodiment, the deimmunized antibody or antigen binding fragment thereof binds to the second fibronectin-like domain of EphB4.

In a further embodiment, the deimmunized antibody or antigen binding fragment thereof is conjugated to a cytotoxic agent. In a further embodiment, the cytotoxic agent is selected from the group consisting of a compound that emits radiation, a molecule of plant, fungal or bacterial origin, such as saporin, a biological protein, vinblastine, 4-desacetylvinblastine, vincristine, leurosidine, and vindesine. In certain embodiments, the antibody or antigen binding fragment thereof is conjugated to a cytotoxic agent through a stable linker which releases the cytotoxic agent inside cancer cells.

In a further embodiment, the antibody or antigen binding fragment inhibits the formation of tubes by cultured endothelial cells. In a further embodiment, the deimmunized antibody or antigen binding fragment thereof inhibits the vascularization of a tissue in vivo. In a further embodiment, the deimmunized antibody or antigen binding fragment thereof decreases the growth of a human tumor xenograft in a mouse. In a further embodiment, the deimmunized antibody or antigen binding fragment thereof inhibits the vascularization of tissue implanted in the cornea of an animal or the vascularization of a Matrigel tissue plug implanted in an animal. In a further embodiment, the deimmunized antibody or antigen binding fragment thereof promotes apoptosis.
In some embodiments, the effector function of the deimmunized antibody or antigen binding fragment thereof is altered. In another embodiment, the effector function of the deimmunized antibody or antigen binding fragment thereof is increased. In another embodiment, the effector function of the deimmunized antibody or antigen binding fragment thereof is decreased. In some embodiments, the deimmunized antibody or antigen binding fragment comprises a heavy chain constant region. In some embodiments, the N-glycosylation in the Fc region is removed.

In a further embodiment, the heavy chain variable region of the deimmunized antibody or antigen binding fragment thereof includes a) an FR1 selected from the group consisting of amino acids 1-30 of SEQ ID NO:10, SEQ ID NO:11, and SEQ ID NO:13; b) an FR2 selected from the group consisting of amino acids 36-49 of SEQ ID NO:10, and SEQ ID NO:13; c) an FR3 selected from the group consisting of amino acids 67-98 of SEQ ID NO:10, SEQ ID NO:11, SEQ ID NO:12, and SEQ ID NO:14; and d) an FR4 consisting of amino acids 113-123 of SEQ ID NO:10; wherein the light chain variable region includes a) an FR1 selected from the group consisting of amino acids 1-23 of SEQ ID NO:15, and SEQ ID NO:16; b) an FR2 selected from the group consisting of amino acids 35-49 of SEQ ID NO:15, and SEQ ID NO:18; c) an FR3 selected from the group consisting of amino acids 57-88 of SEQ ID NO:15, and SEQ ID NO:17; and d) an FR4 consisting of amino acids 98-107 of SEQ ID NO:15.

In a further embodiment, the heavy chain variable region includes an amino acid sequence selected from the group consisting of: a) SEQ ID NO:10; b) SEQ ID NO:11; c) SEQ ID NO:12; d) SEQ ID NO:13; and e) SEQ ID NO:14.

In a further embodiment, the light chain variable region includes an amino acid sequence selected from the group consisting of: a) SEQ ID NO:15; b) SEQ ID NO:16; c) SEQ ID NO:17; and d) SEQ ID NO:18.

In a further embodiment, the heavy chain variable region includes the amino acid sequence of SEQ ID NO:13, and the light chain variable region includes an amino acid sequence selected from the group consisting of: a) SEQ ID NO:17 and b) SEQ ID NO:18.

In a further embodiment, the heavy chain variable region includes the amino acid sequence of SEQ ID NO:14, and the light chain variable region includes an amino acid sequence selected from the group consisting of: a) SEQ ID NO:17 and b) SEQ ID NO:18. In a further embodiment, the heavy chain variable region includes the amino acid sequence of SEQ ID NO:14, and the light chain variable region includes the amino acid sequence of SEQ ID NO:18.

In one embodiment, the deimmunized antibody or antigen binding fragment that binds to the extracellular domain of EphB4 with the same or greater affinity than the parent or nonhuman antibody comprises a heavy chain variable region and a light chain variable region. The deimmunized antibody or antigen binding fragment has one or more of the following characteristics: a) each variable region is derived entirely from one or more human antibodies; b) each variable region has a reduced number of T-cell epitopes compared to the parent or nonhuman antibody; and c) each variable region has a reduced number of B-cell epitopes compared to the parent or nonhuman antibody. In one embodiment, each variable region is a composite of segments from one or more human antibodies. In one embodiment, the human antibody segments are from 2 to 35 amino acids in length. In one embodiment, the human antibody segments do not comprise an entire CDR or individual framework region. In a further embodiment, one or more of the following residues are present in the heavy chain variable region: value at position 5, lysine at position 12, alanine at position 40, arginine at position 66, threonine at position 75, and arginine at position 83, said positions according to the Kabat numbering system. In a further embodiment, one or more of the following residues are present in the light chain variable region: lysine at position 45, threonine at position 74, and glutamine at position 100, said positions according to the Kabat numbering system.

In a further embodiment, the heavy chain variable region comprises a CDR1 comprising SEQ ID NO:25, a CDR2 comprising SEQ ID NO:26, and a CDR3 comprising SEQ ID NO:27; and the light chain variable region comprises a CDR1 comprising SEQ ID NO:28, a CDR2 comprising SEQ ID NO:29, and a CDR3 comprising SEQ ID NO:30. In a further embodiment, the heavy chain variable region comprises a) an FR1 selected from the group consisting of amino acids 1-30 of SEQ ID NO:10, SEQ ID NO:11, and SEQ ID NO:13; b) an FR2 selected from the group consisting of amino acids 36-49 of SEQ ID NO:10, and SEQ ID NO:13; c) an FR3 selected from the group consisting of amino acids 67-98 of SEQ ID NO:10, SEQ ID NO:11, SEQ ID NO:12, and SEQ ID NO:14; and d) an FR4 consisting of amino acids 113-123 of SEQ ID NO:10; and the light chain variable region comprises a) an FR1 selected from the group consisting of amino acids 1-23 of SEQ ID NO:15, and SEQ ID NO:16; b) an FR2 selected from the group consisting of amino acids 35-49 of SEQ ID NO:15, and SEQ ID NO:18; c) an FR3 selected from the group consisting of amino acids 57-88 of SEQ ID NO:15, and SEQ ID NO:17; and d) an FR4 consisting of amino acids 98-107 of SEQ ID NO:15.

In another embodiment, the heavy chain variable region comprises a CDR1 comprising SEQ ID NO:19, a CDR2 comprising SEQ ID NO:20, and a CDR3 comprising SEQ ID NO:21; and wherein the light chain comprises a CDR1 comprising SEQ ID NO:22, a CDR2 comprising SEQ ID NO:23, and a CDR3 comprising SEQ ID NO:24. In a further embodiment, the heavy chain variable region comprises a) an FR1 selected from the group consisting of amino acids 1-30 of SEQ ID NO:1, SEQ ID NO:3, and SEQ ID NO:4, b) an FR2 selected from the group consisting of amino acids 36-49 of SEQ ID NO:1, SEQ ID NO:3, and SEQ ID NO:5; c) an FR3 selected from the group consisting of amino acids 67-98 of SEQ ID NO:1, SEQ ID NO:2, SEQ ID NO:3, SEQ ID NO:4, and SEQ ID NO:5; and d) an FR4 consisting of amino acids 113-123 of SEQ ID NO:1; and the light chain variable region comprises a) an FR1 consisting of amino acids 1-23 of SEQ ID NO:6, b) an FR2 selected from the group consisting of amino acids 35-49 of SEQ ID NO:6, SEQ ID NO:7, and SEQ ID NO:9; c) an FR3 selected from the group consisting of amino acids 57-88 of SEQ ID NO:6, SEQ ID NO:7, and SEQ ID NO:8; and d) an FR4 consisting of amino acids 98-107 of SEQ ID NO:6.

In one embodiment, the deimmunized antibody or antigen binding fragment thereof that binds to the extracellular domain of EphB4 is less immunogenic than the #131 antibody obtained from a hybridoma having an ATCC deposit number PTA-614 and binds with the same or greater affinity than the antibody obtained from a hybridoma. In a further embodiment, heavy chain variable region of the deimmunized antibody or antigen binding fragment comprises a CDR1 comprising SEQ ID NO:25, a CDR2 comprising SEQ ID NO:26, and a CDR3 comprising SEQ ID NO:27; and the light chain variable region comprises a CDR1 comprising SEQ ID NO:28, a CDR2 comprising SEQ ID NO:29, and a CDR3 comprising SEQ ID NO:30. In a further embodiment, the heavy chain variable region comprises a) an FR1 selected from the group consisting of amino acids 1-30 of SEQ ID NO:10, SEQ ID NO:11, and SEQ ID NO:13; b) an FR2
selected from the group consisting of amino acids 36-49 of SEQ ID NO:10, and SEQ ID NO:13; c) an FR3 selected from the group consisting of amino acids 67-98 of SEQ ID NO:10, SEQ ID NO:11, SEQ ID NO:12, and SEQ ID NO:14; and d) an FR4 consisting of amino acids 113-123 of SEQ ID NO:10; and the light chain variable region comprises a) an FR1 selected from the group consisting of amino acids 1-23 of SEQ ID NO:15, and SEQ ID NO:16, b) an FR2 selected from the group consisting of amino acids 35-49 of SEQ ID NO:15, and SEQ ID NO:17; and d) an FR4 consisting of amino acids 98-107 of SEQ ID NO:15.

In one embodiment, the deimmunized antibody or antigen binding fragment thereof that binds to the extracellular domain of EphB4 is less immunogenic than the #47 antibody obtained from a hybridoma having an ATCC deposit number PTA 11338 and binds with the same or greater affinity than the antibody obtained from a hybridoma. In a further embodiment, the heavy chain variable region of the deimmunized antibody or antigen binding fragment comprises a) a CDR1 comprising SEQ ID NO:19, a CDR2 comprising SEQ ID NO:20, and a CDR3 comprising SEQ ID NO:21; and the light chain comprises a CDR1 comprising SEQ ID NO:22, a CDR2 comprising SEQ ID NO:23, and a CDR3 comprising SEQ ID NO:24. In a further embodiment, the heavy chain variable region comprises a) an FR1 selected from the group consisting of amino acids 1-30 of SEQ ID NO:1, SEQ ID NO:3, and SEQ ID NO:4, b) an FR2 selected from the group consisting of amino acids 36-49 of SEQ ID NO:1, SEQ ID NO:3, and SEQ ID NO:5; c) an FR3 selected from the group consisting of amino acids 67-98 of SEQ ID NO:1, SEQ ID NO:2, SEQ ID NO:3, SEQ ID NO:4, and SEQ ID NO:5; and d) an FR4 consisting of amino acids 113-123 of SEQ ID NO:1; and the light chain variable region comprises a) an FR1 consisting of amino acids 1-23 of SEQ ID NO:6, b) an FR2 selected from the group consisting of amino acids 35-49 of SEQ ID NO:6, SEQ ID NO:7, and SEQ ID NO:9; c) an FR3 selected from the group consisting of amino acids 57-88 of SEQ ID NO:6, SEQ ID NO:7, and SEQ ID NO:8; and d) an FR4 consisting of amino acids 98-107 of SEQ ID NO:6.

In one embodiment, the deimmunized antibody or antigen binding fragment that binds to the extracellular domain of EphB4 has a heavy chain variable region that comprises one or more on the following: valine at position 5, lysine at position 12, alanine at position 40, arginine at position 66, threonine at position 75, and arginine at position 83, said positions according to the Kabat numbering system. In a further embodiment, the deimmunized antibody or antigen binding fragment has a light chain variable region that comprises one or more on the following: lysine at position 45, threonine at position 74, and glutamine at position 100, said positions according to the Kabat numbering system.

In one embodiment, a method of reducing the growth rate of a tumor in a subject is provided. In a further embodiment the method includes administering to the subject a therapeutically effective amount of a deimmunized antibody or antigen binding fragment thereof disclosed herein. In one embodiment, the subject is a human subject. In one embodiment, the tumor includes cells expressing EphB4 at a level equal to or less than noncancerous cells of a comparable tissue. In a further embodiment, the subject is a human subject. In one embodiment, the subject includes cells expressing EphB4 at a level higher than noncancerous cells of a comparable tissue. The cancer may be a metastatic cancer. In a further embodiment, the cancer is selected from the group consisting of colon carcinoma, breast tumor, mesothelioma, prostate tumor, squamous cell carcinoma, Kaposi sarcoma, ovarian cancer, and leukemia. In one embodiment, the subject is an angiogenesis-dependent cancer or an angiogenesis independent cancer. In one embodiment, the antibody or antigen-binding fragment may be co-administered with one or more additional anti-cancer chemotherapeutic agents that inhibit cancer cells in an additive or synergistic manner with the antibody or antigen binding fragment.

In certain embodiments, the disclosure provides methods for treating a subject suffering from a cancer, including: identifying the subject as suffering from a malignancy, administering to the subject an antibody or antigen-binding fragment which binds to an extracellular domain of an EphB4 protein. In one embodiment, the subject is a human subject. In a further embodiment, the method includes administering to the subject in need thereof an effective amount of the antibody disclosed herein. In one embodiment, the subject is a human subject. In a further embodiment, the subject is diagnosed with macular degeneration.

In one embodiment, a method may comprise contacting a cell with an amount of a deimmunized antibody or antigen-binding fragment sufficient to inhibit angiogenesis.

In certain aspects, the disclosure provides methods for treating a subject suffering from an angiogenesis-associated disease, including administering to the subject a deimmunized antibody or antigen-binding fragment which binds to an extracellular domain of an EphB4 protein. The antibody or antigen-binding fragment may be formulated with a pharmaceutically acceptable carrier. An angiogenesis related disease may be selected from the group consisting of angiogenesis-dependent cancer, benign tumors, inflammatory disorders, chronic articular rheumatism and psoriasis, ocular angiogenic diseases, Osler-Webber Syndrome, myocardial angiogenesis, plaque neovascularization, telangiectasia, hemophilic joints, angiobroma, wound granulation, wound healing, telangiectasia psoriasis scleroderma, pyogenic granuloma, coronary collaterals, ischemic limb angiogenesis, ruberosis, arthritis, diabetic neovascularization, fractures, vasculogenesis, and homatoipoiesis. An antibody or antigen-binding fragment may be co-administered with at least one additional anti-angiogenesis agent that inhibits angiogenesis in an additive or synergistic manner with the antibody or antigen-binding fragment.

In a further embodiment of the methods of treatment, the deimmunized antibody or antigen binding fragment thereof is administered systemically. In a further embodiment, the deimmunized antibody or antigen binding fragment thereof is administered locally.

In one embodiment, a pharmaceutical composition including a deimmunized antibody or antigen binding fragment thereof disclosed herein is provided. In a further embodiment, the composition may also include any pharmaceutically acceptable carriers or excipients.

In one embodiment the use of the deimmunized antibodies or antigen binding fragments thereof disclosed herein in the manufacture of a medicament for treating cancer is provided. In a further embodiment, the cancer is selected from the group consisting of colon carcinoma, breast tumor, mesothelioma, prostate tumor, squamous cell carcinoma, Kaposi sarcoma, ovarian cancer, and leukemia. In a further embodiment, a use of the deimmunized antibodies or antigen binding fragments
thereof disclosed herein in the manufacture of a medicament for inhibiting angiogenesis is provided.

In one embodiment the deimmunized antibody or antibody binding fragment may inhibit an activity of the EphB4. An antibody may be designed to inhibit the interaction between Ephrin B2 and EphB4. An antagonist antibody will generally affect Eph and/or Ephrin signaling. For example, an antibody may inhibit clustering or phosphorylation of EphB4. In one embodiment, the deimmunized antibody or antibody binding fragment may also increase activity of the EphB4. An agonist antibody, for example, may upregulate EphB4 signaling.

In certain aspects the disclosure provides methods of inhibiting signaling through Ephrin B2/EphB4 pathway in a cell. A method may comprise contacting the cell with an effective amount of antibody or antibody binding fragment which binds to an extracellular domain of an EphB4 protein and inhibiting activity of the EphB4.

In certain embodiments, the deimmunized antibody or antibody binding fragment may be a polyclonal antibody, a monoclonal antibody or antibody fragment, a recombinant antibody, a diabody, a chimerized or chimeric antibody or antibody fragment, a humanized antibody or antibody fragment, a fully human antibody or antibody fragment, a CDR-grafted antibody or antibody fragment, a single chain antibody, an Fv, an Fab, an Fab', or an F(ab')2, and synthetic or semi-synthetic antibodies.

In certain embodiments, the deimmunized antibody or antibody fragment binds to an extracellular domain of an EphB4 protein with a dissociation constant (Kd) of at least about 1×10⁻³ M, at least about 1×10⁻⁴ M, at least about 1×10⁻⁵ M, at least about 1×10⁻⁶ M, at least about 1×10⁻⁷ M, at least about 1×10⁻⁸ M, at least about 1×10⁻⁹ M, at least about 1×10⁻¹⁰ M, at least about 1×10⁻¹¹ M, or at least about 1×10⁻¹² M, to an extracellular domain of an EphB4 protein.

In certain aspects, the deimmunized antibody or antibody fragment disclosed herein may be covalently linked (or otherwise stably associated with) an additional functional moiety, such as a label or a moiety that confers desirable pharmacokinetic properties. Exemplary labels include those that are suitable for detection by a method selected from the group consisting of: fluorescence detection methods, positron emission tomography detection methods and nuclear magnetic resonance detection methods. Labels may, for example, be selected from the group consisting of: a fluorescent label, a radioactive label, and a label having a distinctive nuclear magnetic resonance signature. Moieties such as a polyethylene glycol (PEG) moiety may be affixed to an antibody or antigen binding portion thereof to increase serum half-life. In certain embodiments, the deimmunized antibody or antibody fragment includes an altered constant region, wherein said antibody or antigen-binding fragment exhibits decreased effector function relative to an anti-EphB4 antibody with a native constant region. In certain embodiments, decreased effector function includes one or more properties of the following group: decreased antibody-dependent T-cell-mediated cytotoxicity (ADCC), and decreased complement dependent cytotoxicity (CDC) compared to an anti-EphB4 antibody with a native constant region.

In certain embodiments, the deimmunized antibody or antigen binding fragment thereof includes an altered constant region, wherein said antibody or antigen-binding fragment exhibits increased effector function relative to an anti-EphB4 antibody with a native constant region. In certain embodiments, increased effector function includes one or more properties of the following group: increased antibody-dependent T-cell-mediated cytotoxicity (ADCC), and increased complement dependent cytotoxicity (CDC), compared to an anti-EphB4 antibody with a native constant region.

In certain embodiments, the deimmunized antibody or antigen-binding fragment thereof has an anti-cancer activity. In certain embodiments, the anti-cancer activity may be inhibiting tumor growth, inhibiting cancer cell proliferation, inhibiting cancer cell migration, inhibiting metastasis of cancer cells, inhibiting angiogenesis, or causing tumor cell death.

In one embodiment, the application provides a diagnostic composition including an antibody of the application for detecting prostate cancer.

In one embodiment, the disclosure provides a deimmunized antibody or antigen binding fragment thereof that binds to an epitope situated in the extracellular portion of EphB4. The deimmunized antibody or antigen binding fragment thereof may bind to an epitope situated within amino acids 16-108 of the EphB4 sequence of FIG. 1. For example, the epitope may be situated within the globular domain (amino acids 29-197 of FIG. 1) of EphB4, which binds to EphrinB2.

The deimmunized antibody or antigen binding fragment thereof may inhibit the binding of EphB4 to the extracellular portion of EphrinB2. The deimmunized antibody or antigen binding fragment thereof may bind to an epitope situated within amino acids 327-427 or 428-537 of the EphB4 sequence of FIG. 1. For example, the deimmunized antibody or antigen binding fragment thereof may bind to the first fibronectin-like domain (amino acids 324-429 of FIG. 1) or the second fibronectin-like domain (amino acids 434-526 of FIG. 1) of EphB4.

In other embodiments the antibody or antigen binding fragment is clinically acceptable for administration to a human.

In other embodiments, polynucleotides including a nucleotide sequence encoding the deimmunized antibody or antigen binding fragment thereof disclosed herein are provided. In other embodiments, polynucleotides that hybridize under stringent conditions to polynucleotides encoding the deimmunized antibody or antigen binding fragment thereof disclosed herein are provided.

In other embodiments, vectors including one or more nucleotide sequences encoding the deimmunized antibody or antigen binding fragment thereof disclosed herein are provided.

In other embodiments, isolated cells including a vector that expresses the deimmunized antibody or antigen binding fragment thereof disclosed herein are provided.

The application contemplates combinations of any of the foregoing aspects and embodiments.

FIG. 1 shows the amino acid sequence of the EphB4 precursor protein, (Genbank accession number NP_004435 and SEQ ID NO:53).

FIGS. 2A-2D show amino acid alignments comparing the variable regions from the parental mouse monoclonal antibodies and the deimmunized variants. FIG. 2A depicts the heavy chain variable region of mouse monoclonal antibody #47 (SEQ ID NO:49) aligned with 5 deimmunized variants; FIG. 2B depicts the light chain variable region of #47 (SEQ ID NO:50) aligned with 4 deimmunized variants; FIG. 2C depicts the heavy chain variable region of mouse monoclonal antibody #131 (SEQ ID NO:51) aligned with 5 deimmunized variants; FIG. 2D depicts the light chain variable region of #131 (SEQ ID NO:52) aligned 4 deimmunized variants. Shaded residues indicate amino acids that differ from the parent mouse monoclonal antibody.
FIG. 3A depicts the results of extracellular EphB4 sandwich ELISA comparing the binding of a chimeric #47 antibody with 4 deimmunized #47 variant antibodies. The numbers indicate the sequence of the variable region. For example, “3’/7” indicates an antibody with a heavy chain variable region of SEQ ID NO: 3 and a light chain variable region of SEQ ID NO: 7. FIG. 3B shows the concentration of each antibody where 50% binding in the ELISA is reached. FIG. 4A depicts the results of extracellular EphB4 sandwich ELISA comparing the binding of a chimeric #131 antibody with 4 deimmunized #131 variant antibodies. FIG. 4B shows the concentration of each antibody where 50% binding in the ELISA is reached. FIG. 5 shows a western blot of an SDS gel loaded with lysate from HT29 cells that were treated with 10 mg/ml of antibody (Lane 1: no antibody treatment, Lane 2: mouse monoclonal #131, Lane 3: chimeric #131, Lane 4: an exemplary deimmunized #131 antibody, Lane 5: mouse monoclonal #47, Lane 6: chimeric #47, Lane 7: and exemplary deimmunized #47 antibody, Lane 8 indicated the molecular markers with the weight in KDa). The blot was probed with an anti-EphB4 primary antibody.

FIGS. 6A and 6B depict the results of an in vivo squamous cell carcinoma xenograft assay. Tumor volume is expressed on the Y-axis as mm³ and the X-axis corresponds to the number of days following the beginning of treatment. Treatment with the mouse monoclonal antibodies #47 and #131 are compared with an exemplary deimmunized antibodies and control treatment.

DETAILED DESCRIPTION OF THE INVENTION

1. Definitions

A “subject” refers to a vertebrate, such as for example, a mammal, or a human. Though the antibodies and antigen binding fragments of the present application are primarily concerned with the treatment of human subjects, they may also be employed for the treatment of other mammalian subjects such as dogs and cats for veterinary purposes.

As used herein, the terms “antibody” and “antibodies” (immunoglobulins) encompass, but are not limited to, monoclonal antibodies (including full-length monoclonal antibodies), polyclonal antibodies, multispecific antibodies (e.g., bispecific antibodies) formed from at least two intact antibodies, human antibodies, humanized antibodies, camelid antibodies, chimeric antibodies, single-chain Fvs (scFv), single-chain antibodies, single domain antibodies, domain antibodies, Fab fragments, F(ab')2 fragments, antibody fragments that exhibit the desired biological activity, disulfide-linked Fvs (dsFv), intrabodies, and epitope-binding fragments or antigen binding fragments of any of the above. Antibodies include immunoglobulin molecules and immunoologically active fragments of immunoglobulin molecules, i.e., molecules that contain an antigen-binding site. Immunoglobulin molecules can be of any type (e.g., IgG, IgE, IgM, IgD, IgA, and IgY), class (e.g., IgG1, IgG2, IgG3, IgG4, IgA1 and IgA2) or subclass.

The term “antigen-binding fragment” refers to any portion of an antibody that retains binding to the antigen. An exemplary antigen-binding fragment of an antibody is the heavy chain and/or light chain CDR, or the heavy and/or light chain variable region.

The term “immunogenicity” refers to the ability of an antibody or antigen binding fragment to elicit an immune response (humoral or cellular) when administered to a recipient and includes, for example, the HAMA response. A HAMA response is initiated when T-cells from a subject make an immune response to the administered antibody. The T-cells then recruit B-cells to generate specific “anti-antibody” antibodies.

The term “T-cell epitopes” refers to specific peptide sequences which either bind with reasonable efficiency to MHC class I molecules or which are able to stimulate T-cells via presentation on MHC class II.

The term “B-cell epitopes” refers to peptide sequences recognized by B-cells. In general these sequences are solvent accessible.

The term deimmunization is a process that reduces the immunogenicity of a compound to a given species. A deimmunized antibody is an antibody that has lower immunogenicity in a given species than the corresponding parent or nonhuman antibody.

As used herein, the terms Ephrin and Eph are used to refer, respectively, to ligands and receptors. They can be from any of a variety of animals (e.g., mammals/non-mammals, vertebrates/non-vertebrates, including humans). The nomenclature in this area has changed rapidly and the terminology used herein is that proposed as a result of work by the Eph Nomenclature Committee, which can be accessed, along with previously-used names on the world wide web.

II. Overview

The Eph family receptors are a family of receptor protein-tyrosine kinases which are related to Eph, a receptor named for its expression in an erythropoietin-producing human hepatocellular carcinoma cell line. They are divided into two subgroups on the basis of the relatedness of their extracellular domain sequences and their ability to bind preferentially to Ephrin-A proteins or Ephrin-B proteins. Receptors which interact preferentially with Ephrin-A proteins are EphA receptors and those which interact preferentially with Ephrin-B proteins are EphB receptors.

Eph receptors have an extracellular domain composed of the ligand-binding globular domain, a cysteine rich region followed by a pair of fibronectin type III repeats. The cytoplasmic domain consists of a juxtamembrane region containing two conserved tyrosine residues; a protein tyrosine kinase domain; a sterile α-motif (SAM) and a PDZ-domain binding motif. EphB4 is specific for the membrane-bound ligand EphB2 (Sakano, S. et al 1996; Brambilla R. et al 1995). Ephrin B2 belongs to the class of Eph ligands that have a transmembrane domain and cytoplasmic region with five conserved tyrosine residues and PDZ domain. Eph receptors are activated by binding of clustered, membrane attached ephrins (Davis S. et al, 1994), indicating that contact between cells expressing the receptors and cells expressing the ligands is required for Eph activation.

Upon ligand binding, an Eph receptor dimerizes and auto-phosphorylates the juxtamembrane tyrosine residues to acquire full activation (Kalo M S et al, 1999, Binns K S, 2000). In addition to forward signaling through the Eph receptor, reverse signaling can occur through the ephrin B3. Eph engagement of ephrins results in rapid phosphorylation of the conserved intracellular tyrosines (Bruckner K, 1997) and somewhat slower recruitment of PDZ binding proteins (Palmer A 2002).

The EphB4 precursor protein is depicted in FIG. 1. Amino acids 16-198 of the EphB4 sequence of FIG. 1 correspond to the Globular Domain (GD) of EphB4 that binds to EphrinB2. Amino acids 239-321 correspond to the cysteine rich domain and amino acids 324-429 and 434-526 correspond to the first
fibronectin-like domain (FND1) and the second fibronectin-like domain (FND2) of EphB4 respectively.


The disclosure provides deimmunized antibodies and antigen binding fragments that may be used to treat cancer as well as angiogenesis related disorders and unwanted angiogenesis related processes.

Deimmunized antibodies and antigen binding fragments may be used to inhibit EphB4 function in vitro and in vivo. The disclosure provides antibodies that act as receptor antagonists, such as by inhibiting EphB4 and EphB2 interaction. The disclosure also provides antibodies and antigen binding portions thereof that act as agonists and activate EphB4 kinase activity (typically assessed by evaluating EphB4 phosphorylation state). Surprisingly, such antibodies also inhibit EphB4 functions in cell based and in vivo assays.

Accordingly, such antibodies and antigen binding fragments may be used to inhibit EphB4 function in vitro and in vivo, and for treating cancer or disorders associated with unwanted angiogenesis. While not wishing to be limited to any particular mechanism, it is expected that antibodies which stimulate EphB4 kinase activity, also affect EphB4 removal from the membrane, thus decreasing overall EphB4 levels.

III. Antibodies

Antibodies are proteins produced by lymphocytes known as B-cells in vertebrates in response to stimulation by antigens. The basic structural unit of an antibody (or rather immunoglobulin (Ig)) molecule consists of four polypeptide chains which come together in the shape of a capital letter “Y”. Two of the four chains are identical light (L) chains and are identical heavy (H) chains. There are five different kinds (isotypes) of heavy chains which divide antibodies into five classes, namely, IgA, IgD, IgE, IgG and IgM. In addition, there are two different isotypes of light chains designated kappa and lambda. Each class of heavy chains can combine with either of the light chains. The heavy and light chains each contain a variable region (VH and VL, respectively) that is involved in antigen binding and a constant (C) region. The antigen binding site is composed of six hypervariable regions (or rather complementarity determining regions (CDRs)). Three CDRs from the heavy chain and three CDRs from the light chain are respectively positioned between four relatively conserved anti-parallel beta-sheets which are called framework regions (FR1, FR2, FR3 and FR4), on each chain. By convention, numbering systems have been utilized to designate the location of the component parts of VH and VL chains. The Kabat definition is based on sequence variability and the Chothia definition is based on the location of structural loop regions. The Kabat definition for numbering is used herein.

In certain aspects, the present application provides deimmunized antibodies and antigen binding fragments against EphB4. Is some embodiments the deimmunized antibody or antigen binding fragment binds to an extracellular domain of EphB4. It is understood that antibodies may be Fab, Fv, scFv, Fab’ and F(ab’)2, monoclonal and polyclonal antibodies, engineered antibodies (including chimeric, single chain, CDR-grafted, humanized, fully human antibodies, and artificially selected antibodies), and synthetic or semi-synthetic antibodies produced using phage display or alternative techniques.

In one embodiment of the application, the antibody fragments are truncated chains (truncated at the carboxyl end). In certain embodiments, these truncated chains possess one or more immunoglobulin activities (e.g., complement fixation activity). Examples of truncated chains include, but are not limited to, Fab fragments (consisting of the VL, VH, CL and CH1 domains); Fd fragments (consisting of the VH and CH1 domains); Fv fragments (consisting of VH and VH domains of a single chain of an antibody); Fab’ fragments (consisting of a VH domain); isolated CDR regions; (Fab)2 fragments, bivalent fragments (comprising two Fab fragments linked by a disulphide bridge at the hinge region). The truncated chains can be produced by conventional biochemical techniques, such as enzyme cleavage, or recombinant DNA techniques, each of which is known in the art. These polypeptide fragments may be produced by proteolytic cleavage of intact antibodies by methods well known in the art, or by inserting stop codons at the desired locations in the vectors using site-directed mutagenesis, such as after CH1 to produce Fab fragments or after the hinge region to produce (Fab)2 fragments. Single chain antibodies may be produced by joining VL- and VH-coding regions with a DNA that encodes a peptide linker connecting the VL and VH protein fragments.

This application also provides fragments of anti-EphB4 antibodies, which may comprise a portion of an intact antibody, such as for example, the antigen-binding or variable region of the intact antibody. Examples of antibody fragments include Fab, Fab’, F(ab’)2, and Fv fragments; diabodies; linear antibodies (Zapata et al., Protein Eng. 1995; 8(10): 1057-1062); single-chain antibody molecules; and multispecific antibodies formed from antibody fragments. Papain digestion of antibodies produces two identical antigen-binding fragments, called “Fab” fragments, each with a single antigen-binding site, and a residual “Fc” fragment, whose name reflects its ability to crystallize readily. Pepsin treatment of an antibody yields an F(ab’)2 fragment that has two antigen-combining sites and is still capable of cross-linking antigen. “Fv” usually refers to the minimum antibody fragment that contains a complete antigen-recognition and -binding site. This region consists of a dimer of one heavy- and one light-chain variable region in tight, non-covalent association. It is in this configuration that the three CDRs of each variable region interact to define an antigen-binding site on the surface of the VH-VL dimer. Collectively, the CDRs confer antigen-binding specificity to the antibody. However, even a single variable region (or half of an Fv comprising three CDRs specific for an antigen) has the ability to recognize and bind antigen, although likely at a lower affinity than the entire binding site.

Thus, in certain embodiments, the antibodies disclosed in the application may comprise 1, 2, 3, 4, 5, 6, or more CDRs that recognize the extracellular domain of EphB4.

The Fab fragment also contains the constant domain of the light chain and the first constant domain (CH1) of the heavy chain. Fab’ fragments differ from Fab fragments by the addition of a few residues at the carboxyl terminus of the heavy chain CH1 domain including one or more cysteines from the antibody hinge region. Fab’-SH is the designation herein for Fab’ in which the cysteine residue(s) of the constant domains bear a free thiol group. F(ab’)2 antibody fragments originally were produced as pairs of Fab’ fragments that have hinge cysteines between them. Other chemical couplings of antibody fragments are also known.

“Single-chain Fv” or “scFv” antibody fragments comprise the VH and VL domains of an antibody, wherein these domains
are present in a single polypeptide chain. In certain embodiments, the Fv polypeptide further comprises a polypeptide linker between the V\textsubscript{H} and V\textsubscript{L} domains that enables the scFv to form the desired structure for antigen binding. For a review of scFv see Ploegh in The Pharmacology of Monoclonal Antibodies, vol. 113, Rosenberg and Moore, eds. (Springer-Verlag: New York, 1994), pp. 269-315.

SMIPs are a class of single-chain peptides engineered to include a target binding region and effector domain (CH2 and CH3 domains). See, e.g., U.S. Patent Application Publication No. 20050238646. The target binding region may be derived from the variable region or CDRs of an antibody, e.g., an anti-EphB4 antibody of the application. Alternatively, the target binding region is derived from a protein that binds EphB4.

The term “diabodies” refers to small antibody fragments with two antigen-binding sites, which fragments comprise a heavy-chain variable region (V\textsubscript{H}) connected to a light-chain variable region (V\textsubscript{L}) in the same polypeptide chain (V\textsubscript{H}-V\textsubscript{L}). By using a linker that is too short to allow pairing between the two domains on the same chain, the domains are forced to pair with the complementary domains of another chain and create two antigen-binding sites. Diabodies are described more fully in, for example, EP 404,097; WO 93/1161; and Hollinger et al., Proc. Natl. Acad. Sci. USA, 90: 6444-6448 (1993).

It is well known that the binding to a molecule (or a pathogen) of antibodies with an Fc region assists in the processing and clearance of the molecule (or pathogen). The Fc portions of antibodies are recognized by specialized receptors expressed by immune effector cells. The Fc portions of IgG1 and IgG3 antibodies are recognized by Fc receptors present on the surface of phagocytic cells such as macrophages and neutrophils, which can thereby bind and engulf the molecules or pathogens coated with antibodies of these isotypes (Janeway et al., Immunobiology 5th edition, page 147, Garland Publishing (New York, 2001)).

The anti-EphB4 antibodies of the present application include antibodies having all types of constant regions, including IgM, IgG, IgD, IgA and IgE, and any isotype, including IgG1, IgG2a, IgG2b, IgG3 and IgG4. The light chains of the antibodies can either be kappa light chains or lambda light chains.

In certain embodiments, single chain antibodies, and chimeric, humanized or primatized (CDR-grafted) antibodies, as well as chimeric or CDR-grafted single chain antibodies, comprising portions derived from different species, are also encompassed by the present disclosure as antigen-binding fragments of an antibody. The various portions of these antibodies can be joined together chemically by conventional techniques, or can be prepared as a contiguous protein using genetic engineering techniques. For example, nucleic acids encoding a chimeric or humanized chain can be expressed to produce a contiguous protein. See, e.g., U.S. Pat. Nos. 4,816,567 and 6,331,415; U.S. Pat. No. 4,816,397; European Patent No. 0,120,694; WO 86/01533; European Patent No. 0,194,276 B1; U.S. Pat. No. 5,225,539; and European Patent No. 0,239,400 B1. See also, Newman et al., Biotechnology, 10: 1455-1460 (1992), regarding primatized antibody. See, e.g., Ladner et al., U.S. Pat. No. 4,946,778; and Bird et al., Science, 242: 423-426 (1988), regarding single chain antibodies.

In certain aspects, the present application provides antibodies and antigen binding fragments having binding specificity for an EphB4 or a portion of EphB4. In some aspects the antibodies and antigen binding fragments bind to one or more specific domains of EphB4. For example, an antibody or antigen binding fragment binds to one or more extracellular domains of EphB4 (such as the globular domain, the cysteine-rich domain, and the first fibronectin type 3 domain, and the second fibronectin type 3 domain). In some aspects, the immunoglobulins can bind to EphB4 with a dissociation constant (K\textsubscript{D}) of at least about 1×10-6, 1×10-7, 1×10-8, 1×10-9 M or less. In certain embodiments antibodies and antigen binding fragments disclosed herein are specific for EphB4, with minimal binding to other members of the Eph or Ephrin families. In certain embodiments, the present application provides EphB4 antagonist antibodies. As described herein, the term “antagonist antibody” refers to an antibody that can inhibit one or more functions of an EphB4, such as a binding activity (e.g., ligand binding) and a signaling activity (e.g., clustering or phosphorylation of EphB4, stimulation of a cellular response, such as stimulation of cell migration or cell proliferation). For example, an antagonist antibody can inhibit (reduce or prevent) the interaction of an EphB4 receptor with a natural ligand (e.g., Ephrin B2 or fragments thereof). In some embodiments, an antagonist antibody directed against EphB4 can inhibit functions mediated by EphB4, including endothelial cell migration, cell proliferation, angiogenesis, and/or tumor growth. In certain embodiments, the antagonist antibody binds to an extracellular domain of EphB4.

In other embodiments, antibodies or antigen binding fragments are EphB4 agonists. In some embodiments antibodies or antigen binding fragments activate or enhance EphB4 kinase activity, even independent of EphrinB2. In some instances, such antibodies may be used to stimulate EphB4. However, applicants note that in most cell-based and in vivo assays, such antibodies surprisingly behaved like antagonist antibodies. Such antibodies appear to bind to the fibronectin type III domains, particularly the region of amino acids 327-427 of FIG. 1. In some embodiments, antibodies or antigen binding fragments that bind to the fibronectin type III domains of EphB4 can inhibit functions mediated by EphB4, including endothelial cell migration, cell proliferation, angiogenesis, and/or tumor growth.

In certain embodiments, single chain antibodies, and chimeric, humanized or primatized (CDR-grafted) antibodies, as well as chimeric or CDR-grafted single chain antibodies, comprising portions derived from different species, are also encompassed by the disclosure as antigen binding portions of an antibody.

In addition, antigen binding fragments of antibodies, including fragments of chimeric, humanized, primatized or single chain antibodies, can also be produced. Antigen binding fragments of the subject antibodies retain at least one binding function and/or modulation function of the full-length antibody from which they are derived. Certain antigen binding fragments retain the ability to inhibit one or more functions characteristic of an EphB4, such as a binding activity, a signaling activity, and/or stimulation of a cellular response. For example, in one embodiment, an antigen binding fragment of an EphB4 antibody can inhibit the interaction of EphB4 with one or more of its ligands (e.g., Ephrin B2) and/or can inhibit one or more receptor-mediated functions, such as cell migration, cell proliferation, angiogenesis, and/or tumor growth.

In one aspect, the deimmunized antibody or antigen binding fragment is a mouse antibody. In one aspect, the heavy and light chain variable regions each contain 2 to 20 amino acid substitutions. In one aspect, the substitutions comprise replacing at least one mouse amino acid with at least one corresponding human amino acid. In one aspect, the human amino acid is chosen based on identifying a human germline gene that is homologous to the mouse variable region. In one
aspect, a homologous human germline gene is independently identified for each of the four framework regions of the mouse variable region.

The term "humanized antibody and antigen binding fragment" as used herein refers to an antibody or antigen binding fragment comprising portions of antibody of different origin, wherein at least one portion is of human origin. Accordingly, one embodiment relates to a deimmunized antibody having binding specificity for an EphB4 (e.g., human EphB4), said antibody comprising an antigen binding region of nonhuman origin (e.g., rodent) and at least a portion of an antibody of human origin (e.g., a human framework region, a human constant region or portion thereof). For example, the deimmunized antibody can comprise portions derived from an antibody of nonhuman origin with the requisite specificity, such as a mouse, and from antibody sequences of human origin (e.g., a chimeric antibody), joined together chemically by conventional techniques (e.g., synthetic) or prepared as a contiguous polypeptide using genetic engineering techniques (e.g., DNA encoding the protein portions of the chimeric antibody can be expressed to produce a contiguous polypeptide chain).

In certain embodiments, the framework regions are derived from the closest human germline framework regions. In certain embodiments, the antibody or antigen binding fragment comprises the FR1, FR2, FR3, and FR4 regions from the closest human germline gene. In certain embodiments each framework region is independently selected from the human germline gene closest to the particular framework region. In certain embodiments, residues that affect antigen binding affinity in the framework regions are substituted with the corresponding residues from the nonhuman or parent antibody.

In one aspect a deimmunized antibody or antigen binding fragment contains one or more antibody chains comprising a CDR of nonhuman origin (e.g., one or more CDRs derived from an antibody of nonhuman origin) and a framework region derived from a light and/or heavy chain of human origin, e.g., germline antibody genes (e.g., CDR-grafted antibodies with or without framework changes). In one embodiment, the deimmunized antibody can compete with murine monoclonal antibody for binding to an EphB4 polypeptide. Chimeric or CDR-grafted single chain antibodies are also encompassed by the term humanized antibody.

In one aspect a deimmunized antibody or antigen binding fragment contains one or more antibody chains comprising a CDR of nonhuman origin (e.g., one or more CDRs derived from an antibody of nonhuman origin) and a framework region of nonhuman origin. In one embodiment the nonhuman framework region is substituted with at least one amino acid from a corresponding human framework region. In one embodiment, the substitution of a human amino acid residue for a nonhuman residue reduces the immunogenicity of the antibody in a human subject.

In one embodiment, a deimmunized antibody or antigen binding fragment thereof is provided that binds the extracellular domain of EphB4, including a heavy chain variable region and a light chain variable region, wherein each variable region has between 2 to 20 amino acid substitutions in comparison to a nonhuman or parent antibody that binds the extracellular domain of EphB4. The variable region encompasses three CDR regions interspersed with four framework regions. In one aspect the substitutions are in the framework region.

In one embodiment, a nonhuman or parent antibody is compared to a database of human germline antibody genes, such as from V BASE, and highly homologous individual framework regions are identified. Structural models may be generated of the nonhuman or parent antibody variable region using such programs as SwissPdb, WAM (Web Antibody Modelling), and AbM. Residues, such as those, for example, that do not play a role in interacting with CDRs or antigen or contribute to antigen binding affinity, may be substituted by the corresponding residue from the human germline gene.

In one embodiment, the individual framework regions, instead of the whole framework, in the variable region amino acid sequence of the nonhuman or parent antibody are compared to corresponding sequences in a collection of human antibodies. The human framework with the highest degree of homology is selected to replace the original framework of the nonhuman or parent antibody. This technique, known as "framework patching", is described in detail in US Patent Application No. US 2005/0033028, which is hereby incorporated by reference.

In one embodiment, referred to as "framework shuffling", a combinatorial library with CDR variable regions from the nonhuman or parent antibody are fused in frame into a pool of individual human germline frameworks (Dall’Acqua et al., Methods, 36:43 (2005)). The libraries are then screened to identify clones that encode humanized antibodies which bind the extracellular domain of EphB4 with similar or greater binding affinity compared to the nonhuman or parent antibody.

In one embodiment, the nonhuman or parent antibody is analyzed in order to identify potential T-cell epitopes. T-cell epitopes can be identified using peptide threading software that predicts MHC class II binding motifs. Computational binding prediction algorithms include iTope™, Teptope, SYFPEITHI, and MHCpred. In one embodiment, homologous individual human framework regions are analyzed for potential T-cell epitopes in parallel. Epitopes that are identified in both the nonhuman or parent variable region and the human germline genes may be disregarded. Epitopes identified in only the nonhuman or parent variable region are then flagged for potential replacement.

In one embodiment, the nonhuman or parent antibody is analyzed in order to identify potential B-cell epitopes. Potential B-cell epitopes can be recognized by identifying residues in the non-human or parent antibody framework region that are at least partially solvent accessible and differ from corresponding homologous human antibody framework residues. In one embodiment, potential B-cell epitopes are eliminated by replacing the solvent accessible nonhuman or parent antibody framework residues with corresponding human residues.

In one embodiment substitutions introduced into the deimmunized antibody comprise amino acid substitutions, deletions or insertions. In one embodiment, each substitution results in the replacement of one amino acid with the corresponding amino acid from a homologous human germline gene or from a human variable region consensus sequence. In one embodiment, a nonhuman or parent antibody or antigen binding fragment is deimmunized by substituting from 2 to 20 amino acids with corresponding amino acids from a homologous human germline gene or from a human variable region consensus sequence. In one embodiment, the substitutions may remove one or more T-cell or B-cell epitopes. In another embodiment, the substitutions may introduce a regulatory T-cell epitope. In one embodiment, the deimmunized nonhuman or parent antibody or antigen binding fragment demonstrates a reduced immunogenicity response over the nonhuman or parent antibody or antigen binding fragment when administered to a human subject.
In one embodiment, the heavy and light chain variable regions of the deimmunized antibody or antigen binding fragment are derived entirely from one or more human antibodies, as described in WO2006/082446. In one embodiment, the variable regions are composed of segments of amino acid sequence from one or more human antibodies. In one embodiment, the human segments are two or more amino acids in length. In one embodiment, the human segments are 100 or fewer amino acids in length. In further embodiments, the human segments are 50 or fewer, 40 or fewer, or 30 or fewer amino acids in length.

In one embodiment, each variable region has a reduced number of T-cell epitopes compared to the parent or nonhuman antibody. In one embodiment, each variable region has a reduced number of B-cell epitopes compared to the parent or nonhuman antibody.

In one aspect, the deimmunized antibody or antigen binding fragment comprises the CDR regions of mouse monoclonal antibody #47. Mouse monoclonal antibody #47 has been described and characterized in US2005/0249736, which is hereby incorporated by reference in its entirety. The CDR regions for the heavy chain of mouse monoclonal antibody #47 are defined as SEQ ID NO:19 (CDR1), SEQ ID NO:20 (CDR2), and SEQ ID NO:21 (CDR3). The CDR regions for the light chain of mouse monoclonal antibody #47 are defined as SEQ ID NO:22 (CDR1), SEQ ID NO:23 (CDR2), and SEQ ID NO:24 (CDR3). In one aspect, the deimmunized antibody or antigen binding fragment comprises one or more framework regions (FR1-FR4) of mouse monoclonal antibody #47.

In one aspect the deimmunized antibody or antigen binding fragment is less immunogenic (or rather, elicits a reduced HAMA response) than mouse monoclonal antibody #47 in a human subject. Assays to determine immunogenicity are well within the knowledge of the skilled person. Art-recognized methods of determining immune response can be performed to monitor a HAMA response in a particular subject or during clinical trials. Subjects administered deimmunized antibodies can be given an immunogenicity assessment at the beginning and throughout the administration of said therapy. The HAMA response is measured, for example, by detecting antibodies to the deimmunized therapeutic reagent, in serum samples from the subject using a method known to one in the art, including surface plasmon resonance technology (BLA-CORE) and/or solid-phase ELISA analysis. Alternatively, in vitro assays designed to measure T-cell activation event are also indicative of immunogenicity. One assay, by way of example, is the T-cell proliferation assay. In this assay PHMCs from donors representing >80% of HLA-DR alleles in the world are screened for proliferation in response to an antibody or antibody fragment.

In one aspect the deimmunized antibody or antigen binding fragment binds the extracellular domain of EphB4 with a binding affinity which is at least 80% or at least 90% of the binding affinity of mouse monoclonal antibody #47. In another embodiment, the deimmunized antibody or antigen binding fragment binds the extracellular domain of EphB4 with a binding affinity which is at least 100%, or rather with a greater binding affinity than mouse monoclonal antibody #47.

The determination of binding affinity is well within the knowledge of a skilled person. Art-recognized methods include enzyme-linked immunosorbent assays (ELISAs), radioimmunoprecipitation (RIP) assays, and the BIACore biosensor assay. Example 2 describes in more detail the determination of binding affinity using the sandwich ELISA.

In another aspect, the deimmunized antibody or antigen binding fragment comprises a heavy chain that comprises an amino acid sequence defined as SEQ ID NO:1, SEQ ID NO:2, SEQ ID NO:3, SEQ ID NO:4, or SEQ ID NO:5 and a light chain that comprises an amino acid sequence defined as SEQ ID NO:6, SEQ ID NO:7, SEQ ID NO:8, or SEQ ID NO:9. In one embodiment the heavy chain is SEQ ID NO:3 and the light chain is SEQ ID NO:7. In one embodiment the heavy chain is SEQ ID NO:3 and the light chain is SEQ ID NO:8. In one embodiment the heavy chain is SEQ ID NO:4 and the light chain is SEQ ID NO:7. In one embodiment the heavy chain is SEQ ID NO:4 and the light chain is SEQ ID NO:8. In some of the embodiments the deimmunized antibody or antigen binding fragment binds to the extracellular domain of EphB4. In some of the embodiments the deimmunized antibody or antigen binding fragment is less immunogenic to a human subject than the mouse monoclonal antibody #47.

In one aspect, the deimmunized antibody or antigen binding fragment comprises the CDR regions of mouse monoclonal antibody #131. Mouse monoclonal antibody #131 has been described and characterized in US2005/0249736, which is hereby incorporated by reference in its entirety. The CDR regions for the heavy chain of mouse monoclonal antibody #131 are defined as SEQ ID NO:25 (CDR1), SEQ ID NO:26 (CDR2), and SEQ ID NO:27 (CDR3). The CDR regions for the light chain of mouse monoclonal antibody #131 are defined as SEQ ID NO:28 (CDR1), SEQ ID NO:29 (CDR2), and SEQ ID NO:30 (CDR3). In one aspect, the deimmunized antibody or antigen binding fragment comprises one or more framework regions (FR1-FR4) of mouse monoclonal antibody #131.

In one aspect the deimmunized antibody or antigen binding fragment binds the extracellular domain of EphB4 with a binding affinity which is at least 80% or at least 90% of the binding affinity of mouse monoclonal antibody #131. In another embodiment, the deimmunized antibody or antigen binding fragment binds the extracellular domain of EphB4 with a binding affinity which is at least 100%, or rather with a greater binding affinity than mouse monoclonal antibody #131.

In one aspect the deimmunized antibody or antigen binding fragment is less immunogenic (or rather, elicits a reduced HAMA response) than mouse monoclonal antibody #131 in a human subject.

In another aspect, the deimmunized antibody or antigen binding fragment comprises a heavy chain that comprises an amino acid sequence defined as SEQ ID NO:10, SEQ ID NO:11, SEQ ID NO:12, SEQ ID NO:13, or SEQ ID NO:14 and a light chain that comprises an amino acid sequence defined as SEQ ID NO:15, SEQ ID NO:16, SEQ ID NO:17, or SEQ ID NO:18. In one embodiment the heavy chain is SEQ ID NO:13 and the light chain is SEQ ID NO:17. In one embodiment the heavy chain is SEQ ID NO:13 and the light chain is SEQ ID NO:18. In one embodiment the heavy chain is SEQ ID NO:14 and the light chain is SEQ ID NO:17. In one embodiment the heavy chain is SEQ ID NO:14 and the light chain is SEQ ID NO:18. In some of the embodiments the deimmunized antibody or antigen binding fragment binds to the extracellular domain of EphB4. In some of the embodiments the deimmunized antibody or antigen binding fragment is less immunogenic to a human subject than the mouse monoclonal antibody #131.

In some embodiments, the deimmunized antibodies inhibit the formation of tubes by cultured endothelial cells. Inhibition can be determined by any method known to a person skilled in the art, including the following: Matrigel (60 μl of 10 mg/ml, Collaborative Lab, Cat. No. 35423) is placed in each well of an ice-cold 96-well plate. The plate is allowed to sit at room temperature for 15 minutes then incubated at 37°C.
C. for 30 minutes to permit Matrigel to polymerize. In the mean
time, human umbilical vein endothelial cells are pre-
pared in EGM-2 (Clonetics, Cat. No. CCC3162) at a concentra-
tion of 2x10⁴ cells/ml. The deimmunized antibody or antigen 
binding fragment is prepared at 2x the desired concentration
(5 concentration levels) in the same medium. Cells (500 µl)
and 2x antibody (500 µl) were mixed and 200 µl of this suspen-
sion is placed in duplicate on the polymerized Matrigel.
After 24 h incubation, triplicate pictures are taken for
each concentration using a Bioquant Image Analysis system.
Protein addition effect (IC₅₀) is assessed compared to
untreated controls by measuring the length of cords formed
and number of junctions.

In some embodiments, the deimmunized antibody or anti-
gen binding fragment inhibits the vascularization of a tissue
in vivo. Inhibition can be determined by any method known to
a person skilled in the art, including the following. In
vivo angiogenesis can be assayed in mice as growth of blood
vessels from subcutaneous tissue into a Matrigel plug con-
taining the deimmunized antibody or antigen binding frag-
ment. Matrigel rapidly forms a solid gel at body tempera-
ture, trapping the factors to allow slow release and prolonged expo-
sure to surrounding tissues. Matrigel (8.13 mg/ml, 0.5 ml) in
liquid form at 4°C, is mixed with Endothelial Cell Growth
Supplement (ECGS), deimmunized antibody plus ECGS or
Matrigel plus vehicle alone (PBS containing 0.25% BSA).
Matrigel (0.5 ml) is injected into the abdominal subcutaneous
tissue of female nu/nu mice (6 wks old) along the peritoneal
mid line. At day 6, mice are sacrificed and plugs are recovered
and processed for histology. Typically the overlying skin is
removed, and gels are cut out by retaining the peritoneal
lining for support, fixed in 10% buffered formalin in PBS
and embedded in paraffin. Sections of 3 µm are cut and stained
with H&E or Masson’s trichrome stain and examined under
light microscope.

In some embodiments, the deimmunized antibody or anti-
gen binding fragment decreases the growth of a human tumor
xenograft in a mouse. Inhibition of tumor growth can be
determined by any method known to a person skilled in the
art, including the methods described in the examples.

In some embodiments, the deimmunized antibody or anti-
gen binding fragment inhibits the vascularization of tissue
implanted into the cornea of an animal. Inhibition can be
determined by any method known to a person skilled in the
art, including the mouse corneal micropocket assays per-
formed according to that detailed by Kenyon et al., 1996. (see
US publication 2005/0249736 which is hereby incorporated
by reference).

In some embodiments, the deimmunized antibody or anti-
gen binding fragment promotes apoptosis. Apoptosis can be
examined in vitro using various methods including TUNEL
staining and the Cell Death Detection ELISA Plus Kit (Roche,
Piscataway, N.J.).

In certain aspects, the present application provides the
hybridoma cell lines, as well as to the monoclonal antibodies
produced by these hybridoma cell lines. The cell lines
disclosed have uses other than for the production of the
monoclonal antibodies. For example, the cell lines can be
fused with other cells (such as suitably drug-marked human
myeloma, mouse myeloma, human-mouse heteromyeloma
or human lymphoblastoid cells) to produce additional hybrid-
oma, and thus provide for the transfer of the genes encoding
the monoclonal antibodies. In addition, the cell lines can be
used as a source of nucleic acids encoding the anti-EphB4
immunoglobulin chains, which can be isolated and expressed
(e.g., upon transfer to other cells using any suitable technique
(see e.g., Cabally et al., U.S. Pat. No. 4,816,567, Winter, U.S.
Pat. No. 5,225,539)). For instance, clones comprising a rear-
ranged anti-EphB4 light or heavy chain can be isolated (e.g.,
by PCR) or cDNA libraries can be prepared from mRNA
isolated from the cell lines, and cDNA clones encoding an
anti-EphB4 immunoglobulin chain can be isolated. Thus,
nucleic acids encoding the heavy and/or light chains of the
antibodies or portions thereof can be obtained and used in
accordance with recombinant DNA techniques for the pro-
duction of the specific immunoglobulin, immunoglobulin
chain, or variants thereof (e.g., humanized immunoglobulins)
in a variety of host T-cells or in an in vitro translation system.
For example, the nucleic acids, including cDNAs, or deriva-
tives thereof encoding variants such as a humanized immu-
 noglobulin or immunoglobulin chain, can be placed into suit-
able prokaryotic or eukaryotic vectors (e.g., expression
vectors) and introduced into a suitable host T-cell by an
appropriate method (e.g., transformation, transfection,
electroporation, infection), such that the nucleic acid is oper-
ably linked to one or more expression control elements (e.g.,
in the vector or integrated into the host T-cell genome). For pro-
hosion, host T-cells can be maintained under conditions suitable
for expression (e.g., in the presence of inducer, suitable media
supplemented with appropriate salts, growth factors, antibi-
oc, nutritional supplements, etc.), whereby the encoded
polypeptide is generated. If desired, the encoded protein can
be recovered and/or isolated (e.g., from the host T-cells or
medium). It will be appreciated that the method of production
comprises expression in a host T-cell of a transgenic ani-
mal (see e.g., WO 92/03918, GenPharm International, pub-

The present antibodies and antigen binding fragments can
be utilized to directly kill or ablate cancerous cells in vivo.
Direct killing involves administering the antibodies (which
are optionally fused to a cytotoxic drug) to a subject requiring
such treatment. In some embodiments, the cancer comprises
cancer cells expressing EphB4 at a higher level than non-
cancerous cells of a comparable tissue. Since the antibodies
recognize EphB4 on cancer cells, any such cells to which the
antibodies bind are destroyed. Where the antibodies are used
alone to kill or ablate cancer cells, such killing or ablation
can be effected by initiating endogenous host immune functions,
such as CDC and/or ADCC. Assays for determining whether
an antibody kills cells in this manner are within the purview of
those skilled in the art.

Accordingly in one embodiment, the antibodies of the
present disclosure may be used to deliver a variety of cyto-
toxic compounds. Any cytotoxic compound can be fused to
the present antibodies. The fusion can be achieved chemically
or genetically (e.g., via expression as a single, fused mol-
ecule). The cytotoxic compound can be biological, such as
a polypeptide, or a small molecule. As those skilled in the
art will appreciate, for small molecules, chemical fusion is
used, while for biological compounds, either chemical or genetic
fusion can be employed.

Non-limiting examples of cytotoxic compounds include
therapeutic drugs, a compound emitting radiation, molecules
of plant, fungal, or bacterial origin, biological proteins, and
mixtures thereof. The cytotoxic drugs can be intracellularly
acting cytotoxic drugs, such as short-range radiation emitters,
including, for example, short-range, high-energy α-emitters.
Enzymatically active toxins and fragments thereof are exem-
plified by diphtheria toxin A fragment, nonbinding active
fragments of diptheria toxin, exotoxin A (from Pseudomo-
as aeruginosa), ricin A chain, abrin A chain, modeccin A
chain, α-sarcin, certain Aeurinus fordi proteins, ceratin
Cithin proteins, Phytoecocca americana proteins (PAP,
PAPII and PAP-S), Monodoma charantia inhibitor, curcin, cro-
tin, Saponaria officinalis inhibitor, gelonin, mitogillin, restrictocin, phenomycin, and enomycin, for example. Procedures for preparing enzymatically active polypeptides of the immunotoxins are described in WO84/03508 and WO85/03508, which are hereby incorporated by reference. Certain cytotoxic moieties are derived from adriamycin, chlorambucil, daunomycin, methotrexate, nocarzinostatin, and platinum, for example.

Procedures for conjugating the antibodies with the cytotoxic agents have been previously described and are within the purview of one skilled in the art. In certain embodiments, the antibodies or antigen binding fragments are further attached to a label that is able to be detected (e.g., the label can be a radioisotope, fluorescent compound, enzyme or enzyme co-factor). The active moiety may be a radioactive agent, such as: radioactive heavy metals such as iron chelates, radiolabels of gadolinium or manganese, positron emitters of oxygen, nitrogen, iron, carbon, or gallium. 43K, 52Fe, 57Co, 59Cu, 67Ga, 68Ga, 123I, 131I, 132I, or 99Tc. A binding agent affiliated to such a moiety may be used as an imaging agent and is administered in an amount effective for diagnostic use in a mammal such as a human and the localization and accumulation of the imaging agent is then detected. The localization and accumulation of the imaging agent may be detected by radioscintigraphy, nuclear magnetic resonance imaging, computed tomography or positron emission tomography.

Immunoscintigraphy using antibodies or other binding polypeptides directed at EphB4 may be used to detect and/or diagnose cancers and vasculature. For example, monoclonal antibodies against the EphB4 marker labeled with 99Technetium, 111Indium, 125Iodine—may be effectively used for such imaging. As will be evident to the skilled artisan, the amount of radioisotope to be administered is dependent upon the radioisotope. Those having ordinary skill in the art can readily formulate the amount of the imaging agent to be administered based upon the specific activity and energy of a given radioisotope used as the active moiety. Typically 0.1-100 millicuries per dose of imaging agent, or 1-10 millicuries, or 2-5 millicuries are administered. Thus, the compositions disclosed are useful as imaging agents comprising a targeting moiety conjugated to a radioactive moiety comprised of 0.1-100 millicuries, in some embodiments 1-10 millicuries, in some embodiments 1-5 millicuries.

The application further provides polynucleotides comprising a nucleotide sequence encoding a deimmununized anti-EphB4 antibody or fragments thereof. Because of the degeneracy of the genetic code, a variety of nucleic acid sequences encode each antibody amino acid sequence. The application further provides polynucleotides that hybridize under stringent or lower stringency hybridization conditions, e.g., as defined herein, to polynucleotides that encode a deimmununized antibody that binds to hEphB4.

Stringent hybridization conditions include, but are not limited to, hybridization to filter-bound DNA in 6x sodium chloride/sodium citrate (SSC) at about 45°C followed by one or more washes in 0.2xSSC/0.1% SDS at about 50-65°C, highly stringent conditions such as hybridization to filter-bound DNA in 6xSSC at about 45°C followed by one or more washes in 0.1xSSC/0.2% SDS at about 60°C, or any other stringent hybridization conditions known to those skilled in the art (see, for example, Ausubel, F. M. et al., eds. 1989 Current Protocols in Molecular Biology, vol. 1, Green Publishing Associates, Inc. and John Wiley and Sons, Inc., NY at pages 6.3.1 to 6.3.6 and 2.10.3).

The polynucleotides may be obtained, and the nucleotide sequence of the polynucleotides determined, by any method known in the art. For example, if the nucleotide sequence of the antibody is known, a polynucleotide encoding the antibody may be assembled from chemically synthesized oligonucleotides (e.g., as described in Kuttmeier et al., BioTechniques 17:242 (1994)), which, briefly, involves the synthesis of overlapping oligonucleotides containing portions of the sequence encoding the antibody, annealing and ligating of those oligonucleotides, and then amplification of the ligated oligonucleotides by PCR. In one embodiment, the codons that are used comprise those that are typical for human or mouse (see, e.g., Nakamura, Y., Nucleic Acids Res. 28: 292 (2000)).

A polynucleotide encoding an antibody may also be generated from nucleic acid from a suitable source. If a clone containing a nucleic acid encoding a particular antibody is not available, but the sequence of the antibody molecule is known, a nucleic acid encoding the immunoglobulin may be chemically synthesized or obtained from a suitable source (e.g., an antibody cDNA library, or a cDNA library generated from, or nucleic acid, preferably polya-RNA, isolated from, any tissue or cells expressing the antibody, such as hybridoma cells selected to express an antibody) by PCR amplification using synthetic primers hybridizable to the 5' and 3' ends of the sequence or by cloning using an oligonucleotide probe specific for the particular gene sequence to identify, e.g., a cDNA clone from a cDNA library that encodes the antibody. Amplified nucleic acids generated by PCR may then be cloned into replicable cloning vectors using any method well known in the art.

The present application also provides polynucleotide sequences encoding heavy and light chain framework regions and CDRs of antibodies described herein as well as expression vectors for their efficient expression in mammalian cells.

IV. Anti-EphB4 Antibodies with Altered Effector Functions

Antibodies with engineered or variant constant or Fc regions can be useful in modulating effector functions, such as, for example, antigen-dependent cytotoxicity (ADCC) and complement-dependent cytotoxicity (CDC). Such antibodies with engineered or variant constant or Fc regions may be useful in instances where EphB4 is expressed in normal tissue, for example; deimmununized antibodies and antigen binding fragments without effector function in these instances may elicit the desired therapeutic response while not damaging normal tissue. In another embodiment, antibodies or antigen binding fragments are provided with increased effector function, and may therefore be useful for direct cell killing.

Accordingly, certain aspects and methods of the present disclosure relate to anti-EphB4 antibodies with altered effector functions that comprise one or more amino acid substitutions, insertions, and/or deletions. In certain embodiments, such a variant anti-EphB4 antibody exhibits reduced or no effector function.

Anti-EphB4 antibodies with reduced effector function may be produced by introducing other types of changes in the amino acid sequence of certain regions of the antibody. Such amino acid sequence changes include but are not limited to the Ala-Ala mutation described by Bluestone et al. (see WO 94/28027 and WO 98/47531; also see Xu et al. 2000 Cell Immunol 200, 16-26). Thus in certain embodiments, anti-EphB4 antibodies with mutations within the constant region including the Ala-Ala mutation may be used to reduce or abolish effector function. According to these embodiments,
the constant region of an anti-Eph4B antibody comprises a mutation to an alanine at position 234 or a mutation to an alanine at position 235. Additionally, the constant region may contain a double mutation: a mutation to an alanine at position 234 and a second mutation to an alanine at position 235. In one embodiment, the anti-Eph4B antibody comprises an IgG4 framework, wherein the Ala-Ala mutation would describe a mutation(s) from phenylalanine to alanine at position 234 and/or a mutation from leucine to alanine at position 235. In another embodiment, the anti-anti-Eph4B antibody comprises an IgG1 framework, wherein the Ala-Ala mutation would describe a mutation(s) from leucine to alanine at position 234 and/or a mutation from leucine to alanine at position 235. An anti-anti-Eph4B antibody may alternatively or additionally carry other mutations, including the point mutation K222A in the CH2 domain (Hezareh et al. 2001 J Virol. 75: 12161-8). An antibody with said mutation(s) in the constant region may furthermore be a blocking or non-blocking antibody.

Changes within the hinge region also affect effector functions. For example, deletion of the hinge region may reduce affinity for Fc receptors and may reduce complement activation (Klein et al. 1981 Proc Natl Acad Sci USA. 78: 524-528). The present disclosure therefore also relates to antibodies with alterations in the hinge region.

In particular embodiments, anti-Eph4B antibodies may be modified to either enhance or inhibit complement dependent cytotoxicity (CDC). Modeled CDC activity may be achieved by introducing one or more amino acid substitutions, insertions, or deletions in an Fc region of the antibody (see, e.g., U.S. Pat. No. 6,194,551). Alternatively or additionally, cysteine residue(s) may be introduced in the Fc region, thereby allowing interchain disulfide bond formation in this region. The homodimeric antibody thus generated may have improved or reduced internalization capacity and/or increased or decreased complement-mediated cell killing. See Caron et al., J Exp Med. 176:1191-1195 (1992) and Shaples, B. J. Immunol. 148:2918-2922 (1992), W99/ 51642, Duncan & Winter Nature 322: 738-40 (1988); U.S. Pat. No. 5,648,260; U.S. Pat. No. 5,624,821; and WO94/ 29351. Homodimeric antibodies with enhanced anti-tumor activity may also be prepared using heterobifunctional crosslinkers as described in Wolfe et al. Cancer Research 53:2560-2565 (1993). Alternatively, an antibody can be engineered that has dual Fc regions and may thereby have enhanced complement lysis and ADCC capabilities. See Stevenson et al. Anti-Cancer Drug Design 3:219-230 (1989).

Another potential means of modulating effector function of antibodies includes changes in glycosylation. This topic has been recently reviewed by Raju who summarized the proposed importance of the oligosaccharides found on human IgGs with their degree of effector function (Raju, T. S. BioProcess International April 2003. 44-53). According to Wright and Morrison, the microheterogeneity of human IgG oligosaccharides can affect biological functions such as CDC and ADCC, binding to various Fe receptors, and binding to C6q protein (Wright A. & Morrison S.L. TIBTECH 1997, 15: 26-32). It is well documented that glycosylation patterns of antibodies can differ depending on the producing cell and the cell culture conditions (Raju, T. S. BioProcess International April 2003. 44-53). Such differences can lead to changes in both effector function and pharmacokinetics (Israel et al. Immunology. 1996: 89(4):573-578; Newkirk et al. P. Clin. Exp. 1996; 106(2):259-64). Differences in effector function may be related to the IgG’s ability to bind to the Fc receptors (FcγRs) on the effector cells. Shields, et al., have shown that IgG, with variants in amino acid sequence that have improved binding to FcγR, can exhibit up to 100% enhanced ADCC using human effector cells (Shields et al. J Biol Chem. 2001 276(9):6591-6594). While these variants include changes in amino acids not found at the binding interface, both the nature of the sugar component as well as its structural pattern may also contribute to the differences observed. In addition, the presence or absence of fucose in the oligosaccharide component of an IgG can improve binding and ADCC (Shields et al. J Biol Chem. 2002; 277(30):26733-40). An IgG that lacked a fucosylated carbohydrate linked to Asn292 exhibited normal receptor binding to the Fcγ receptor. In contrast, binding to the FcγRIIA receptor was improved 50% and accompanied by enhanced ADCC, especially at lower antibody concentrations.

Work by Shinkawa, et al., demonstrated that an antibody to the human IL-5 receptor produced in a rat hybridoma showed more than 50% higher ADCC when compared to the antibody produced in Chinese hamster ovary cells (CHO) (Shinkawa et al. J Biol Chem. 2003 278(5):3466-73). Monosaccharide composition and oligosaccharide profiling showed that the rat hybridoma-produced IgG had a lower amount of fucose than the CHO-produced protein. The authors concluded that the lack of fucosylation of an IgG1 has a critical role in enhancement of ADCC activity.

A different approach was taken by Umana, et al., who changed the glycosylation pattern of chCE7, a chimeric IgG1 anti-neuroblastoma antibody (Umana et al. Nat Biotechnol. 1999 February; 17(2): 176-80). Using tetracycline, they regulated the activity of a glycosyltransferase enzyme (GnTII) which bisects oligosaccharides that have been implicated in ADCC activity. The ADCC activity of the parent antibody was barely above background level. Measurement of ADCC activity of the chCE7 produced at different tetracycline levels showed an optimal range of GnTIII expression for maximal chCE7 in vitro ADCC activity. This activity correlated with the level of constant region-associated, bisected complex oligosaccharide. Newly optimized variants exhibited substantial ADCC activity. Similarly, Wright and Morrison produced antibodies in a CHO cell line deficient in glycosylation (1994 J Exp Med 180: 1087-1096) and showed that antibodies produced in this cell line were incapable of complement-mediated cytosis. Thus as known alterations that affect effector function include modifications in the glycosylation pattern or a change in the number of glycosylated residues, the present disclosure relates to an Eph4B antibody wherein glycosylation is altered to either enhance or decrease effector function(s) including ADCC and CDC. Altered glycosylation includes a decrease or increase in the number of glycosylated residues as well as a change in the pattern or location of glycosylated residues.

Still other approaches exist for the altering effector function of antibodies. For example, antibody-producing cells can be Hypermutagenic, thereby generating antibodies with randomly altered nucleotide and polypeptide residues throughout an entire antibody molecule (see WO 2005/01735). Hypermutagenic host cells include cells deficient in DNA mismatch repair. Antibodies produced in this manner may be less antigenic and/or have beneficial pharmacokinetic properties. Additionally, such antibodies may be selected for properties such as enhanced or decreased effector function(s).

It is further understood that effector function may vary according to the binding affinity of the antibody. For example, antibodies with high affinity may be more efficient inactivating the complement system compared to antibodies with relatively lower affinity (Marzocchi-Machado et al. 1999 Immunol Invest 28: 89-101). Accordingly, an antibody may be altered such that the binding affinity for its antigen is reduced
The deimmunized antibody or antigen binding fragment that binds the extracellular domain of EphB4 can be made by a number of different methods known to a person skilled in the art. In one example, a nonhuman anti-EphB4 antibody is deimmunized to reduce the number of either T or B-cell epitopes or to introduce regulatory T-cell epitopes. The starting nonhuman or parent anti-EphB4 antibody can be modified; for example, it can be any form of a chimeric, humanized, or primatized antibody. Alternatively, the starting nonhuman or parent anti-EphB4 antibody is de-immunized without a humanization or primatization step.

Nonhuman EphB4 Antibodies

Nonhuman EphB4 antibodies are known to those skilled in the art and include, for example, the antibodies described in U.S. Pat. No. 5,635,177 and US publications 2006/0134118 and 2005/0249736. Each of these documents is incorporated herein.

Methods of generating novel anti-EphB4 antibodies are also known to those skilled in the art. For example, a method for generating a monoclonal antibody that binds specifically to an EphB4 polypeptide may comprise administering to a mouse an amount of an immunogenic composition comprising the EphB4 polypeptide effective to stimulate a detectable immune response, obtaining antibody-producing cells (e.g., cells from the spleen) from the mouse and fusing the antibody-producing cells with myeloma cells to obtain antibody-producing hybridomas, and testing the antibody-producing hybridomas to identify a hybridoma that produces a monoclonal antibody that binds specifically to the EphB4 polypeptide. Once obtained, a hybridoma can be propagated in a cell culture, optionally in culture conditions where the hybridoma-derived cells produce the monoclonal antibody that binds specifically to EphB4 polypeptide. The monoclonal antibody may be purified from the cell culture.

In addition, the techniques used to screen antibodies in order to identify a desirable antibody may influence the properties of the antibody obtained. A variety of different techniques are available for testing antibody/antigen interactions to identify particularly desirable antibodies. Such techniques include ELISAs, surface plasmon resonance binding assays (e.g., the Biacore binding assay; Bio-core AB, Uppsala, Sweden), sandwich assays (e.g., the paramagnetic bead system of JGI International, Inc., Gaithersburg, Md.), western blots, immunoprecipitation assays and immunohistochemistry.

Other suitable methods of producing or isolating antibodies of the requisite specificity can be used, including, for example, methods which select recombinant antibody from a library, or which rely upon immunization of transgenic animals (e.g., mice) capable of producing a full repertoire of human antibodies. See e.g., Jakovovits et al., Proc. Natl. Acad. Sci. USA, 90: 2551-2555 (1993); Jakovovits et al., Nature, 362: 255-258 (1993); Lonberg et al., U.S. Pat. No. 5,545,806; Surani et al., U.S. Pat. No. 5,545,807.

Antibodies can be engineered in numerous ways. They can be made as single-chain antibodies (including small modular immunopharmaceuticals or SMIPs(TM)), Fab and F(ab')2 fragments, etc. Antibodies can be humanized, chimerized, deimmunized, or fully human. Numerous publications set forth the many types of antibodies and the methods of engineering such antibodies. For example, see U.S. Pat. Nos. 6,352,245; 6,180,370; 5,693,762; 6,407,213; 6,548,640; 5,565,332; 5,225,539; 6,103,889; and 5,260,203.

The application provides antigen binding fragments capable of binding to an EphB4 receptor or portion thereof, including, but not limited to, Fv, Fab, Fab' and F(ab')2 fragments. Such fragments can be produced by enzymatic cleavage or by recombinant techniques. For instance, papain or pepsin cleavage can generate Fab or F(ab')2 fragments, respectively. Antibodies can also be produced in a variety of truncated forms using antibody genes in which one or more stop codons has been introduced upstream of the natural stop site. For example, a chimeric gene encoding a F(ab')2 heavy chain portion can be designed to include DNA sequences encoding the CH1 domain and hinge region of the heavy chain.


Methods for humanizing antibodies have been described in the art. In some embodiments, a humanized antibody has one or more amino acid residues introduced from a source that is nonhuman, in addition to the nonhuman CDRs. Humanization can be essentially performed following the method of Winter and co-workers (Jones et al., Nature, 321:522-525 (1986); Riechmann et al., Nature, 332:323-327 (1988); Verhoeyen et al., Science, 239:1534-1536 (1988)), by substituting hypervariable region sequences for the corresponding sequences of a human antibody. Accordingly, such "humanized" antibodies are chimeric antibodies (U.S. Pat. No. 4,816, 567) wherein substantially less than an intact human variable region has been substituted by the corresponding sequence from a nonhuman species. In practice, humanized antibodies are typically human antibodies in which some hypervariable region residues and possibly some framework region residues are substituted by residues from analogous sites in rodent antibodies.

U.S. Pat. No. 5,693,761 to Queen et al, discloses a refinement on Winter for humanizing antibodies, and is based on the premise that ascribes avidity loss to problems in the structural motifs in the humanized framework which, because of steric or other chemical incompatibility, interfere with the folding of the CDRs into the binding-capable conformation found in the mouse antibody. To address this problem, Queen teaches using human framework sequences closely homologous in linear peptide sequence to framework sequences of the mouse antibody to be humanized. Accordingly, the methods of Queen focus on comparing framework sequences between species. Typically, all available human variable region sequences are compared to a particular mouse sequence and the percentage identity between correspondent
framework residues is calculated. The human variable region with the highest percentage is selected to provide the framework sequences for the humanizing project. Queen also teaches that it is important to retain in the humanized framework, certain amino acid residues from the mouse framework critical for supporting the CDRs in a binding-capable conformation. Potential criticality is assessed from molecular models. Candidate residues for retention are typically those adjacent in linear sequence to a CDR or physically within 6 Ångstrom of any CDR residue.

In other approaches, the importance of particular framework amino acid residues is determined experimentally once a low-avidity humanized construct is obtained, by reversion of single residues to the mouse sequence and assaying antigen binding as described by Ricehmann et al., (1988). Another example approach for identifying important amino acids in framework sequence is disclosed by U.S. Patent No. 5,821,337 to Carter et al., and by U.S. Patent No. 5,859,205 to Adair et al. These references disclose specific Kabat residue positions in the framework, which, in a humanized antibody may require substitution with the corresponding mouse amino acid to preserve avidity.

Another method of humanizing antibodies, referred to as “framework shuffling”, relies on generating a combinatorial library with nontumor CDR variable regions fused in frame into a pool of individual human germline frameworks (Dall’Acqua et al., Methods, 36:43 (2005)). The libraries are then screened to identify clones that encode humanized antibodies which retain good binding.

The choice of human variable regions, both light and heavy, to be used in making the humanized antibodies is very important to reduce antigenicity. According to the so-called “best-fit” method, the sequence of the variable region of a rodent antibody is screened against the entire library of known human variable-domain sequences. The human sequence that is closest to that of the rodent is then accepted as the human framework region (framework region) for the humanized antibody (Sims et al., J. Immunol., 151:2296 (1993); Chothia et al., J. Mol. Biol., 196:901 (1987)). Another method uses a particular framework region derived from the consensus sequence of all human antibodies of a particular subgroup of light or heavy chain variable regions. The same framework may be used for several different humanized antibodies (Carter et al., Proc. Natl. Acad. Sci. USA, 89:4285 (1992); Presta et al., J. Immunol., 151:2623 (1993)).

The choice of nonhuman residues to substitute into the human variable region can be influenced by a variety of factors. These factors include, for example, the rarity of the amino acid in a particular position, the probability of interaction with either the CDRs or the antigen, and the probability of participating in the interface between the light and heavy chain variable domain interface. (see for example U.S. Pat. Nos. 5,693,761, 6,632,927, and 6,639,055). One method to analyze these factors is through the use of three-dimensional models of the nonhuman and humanized sequences. Three-dimensional immunoglobulin models are commonly available and are familiar to those skilled in the art. Computer programs are available that illustrate and display probable three-dimensional conformational structures of selected candidate immunoglobulin sequences. Inspection of these displays permits analysis of the likely role of the residues in the functioning of the candidate immunoglobulin sequence, e.g., the analysis of residues that influence the ability of the candidate immunoglobulin to bind its antigen. In this way, nonhuman residues can be selected and substituted for human variable region residues in order to achieve the desired antibody characteristic, such as increased affinity for the target antigen(s).

Deimmunization

The anti-EphA4 antibody or antigen binding fragment is deimmunized to render it non-immunogenic or less immunogenic, to a given species. Deimmunization can be achieved through structural alterations to the anti-EphA4 antibody. In one embodiment, the anti-EphA4 is a mouse monoclonal antibody. Any deimmunization technique known to those skilled in the art can be employed. One suitable technique, for example, for deimmunizing antibodies is described in WO 00/34317, the disclosure of which is incorporated herein in its entirety. In summary, a typical protocol within the general method described therein includes the following steps:

1. Determining the amino acid sequence of the antibody or a part thereof;
2. Identifying potential T-cell epitopes within the amino acid sequence of the antibody by any method including determination of the binding of peptides to MHC molecules, determination of the binding of peptide:HLA complexes to the T-cell receptors from the species to receive the therapeutic protein, testing of the antibody or parts thereof using transgenic animals with HLA molecules of the species to receive the therapeutic protein, or testing such transgenic animals reconstituted with immune system cells from the species to receive the therapeutic protein;
3. By genetic engineering or other methods for producing modified antibodies, altering the antibody to remove one or more of the potential T-cell epitopes and producing such an altered antibody for testing.

In one embodiment, the sequences of the variable regions of the antibody or antigen binding fragment can be analyzed for the presence of MHC class II binding motifs. For example, a comparison may be made with databases of MHC-binding motifs such as, for example, by searching the “motifs” database on the worldwide web. Alternatively, MHC class II binding peptides may be identified using computational threading methods such as those devised by Altuvia et al. (J. Mol. Biol. 249 244-250 (1995)) whereby consecutive overlapping peptides from the variable region sequences are testing for their binding energies to MHC class II proteins. Computational binding prediction algorithms include iTope™, Tepitope, SYFPEITHI, and MHCpred. In order to assist the identification of MHC class II-binding peptides, associated sequence features which relate to successfully presented peptides such as amphipathicity and Rothbard motifs, and cleavage sites for cathepsin B and other processing enzymes can be searched for.

Having identified potential second species (e.g. human) T-cell epitopes, these epitopes are then eliminated by alteration of one or more amino acids, as required to eliminate the T-cell epitope. Usually, this will involve alteration of one or more amino acids within the T-cell epitope itself. This could involve altering an amino acid adjacent the epitope in terms of the primary structure of the protein or which is not adjacent in the primary structure but is adjacent in the secondary structure of the molecule. The usual alteration contemplated will be amino acid substitution, but it is possible that in certain circumstances amino acid addition or deletion will be appropriate. All alterations can be accomplished by recombinant DNA technology, so that the final molecule may be prepared by expression from a recombinant host, for example by well established methods, but the use of protein chemistry or any other means of molecular alteration may also be used.

In practice, it has been recognized that potential human T-cell epitopes can be identified even in human germline
variable region framework sequences when comparison is made with databases of MHC-binding motifs. As humans do not generally mount an ongoing immune response against their own antibodies, then either humans are tolerant to these epitopes or these potential epitopes cannot be presented by human APCs because they are not processed appropriately. Therefore, such potential T-cell epitopes which are represented in germline variable region sequences may, in practice, be retained in the deimmunized antibody.


In one method, a human germline sequence homologous to the nonhuman or parental sequence is identified. Alternatively, a human germline sequence homologous to each framework region (FR1-FR4) of the nonhuman or parental sequence may be identified. In one method, the nonhuman or parental sequence and the homologous human germline sequence are analyzed in parallel for MHC class II binding peptides. Regions can be identified where the MHC class II binding profile differ between the nonhuman or parental sequence and a human germline sequence. Amino acids in these regions of the nonhuman or parental sequence can be selected for conversion to a corresponding human amino acid.

Once identified T-cell epitopes are removed, the deimmunized sequence may be analyzed again to ensure that new T-cell epitopes have not been created and, if they have, the epitope(s) can be deleted, as described above; or the previous conversion to a corresponding human germline amino acid is altered by conversion of the nonhuman or parental amino acid to a corresponding human amino acid until all T-cell epitopes are eliminated.

Not all T-cell epitopes identified computationally need to be removed. A person skilled in the art will appreciate the significance of the “strength” or rather potential immunogenicity of particular epitopes. The various computational methods generate scores for potential epitopes. A person skilled in the art will recognize that only the high scoring epitopes need to be removed. A skilled person will also recognize that there is a balance between removing potential epitopes and maintaining the original nonhuman variable region sequence, which may affect antigen binding. Therefore, one strategy is to sequentially introduce substitutions into the nonhuman or parent antibody and then test for antigen binding and immunogenicity.

For the CDRs of a therapeutic antibody, it is common for one or more potential T-cell epitopes to overlap or fall within the CDRs whereby removal of the epitopes requires alteration of residues within the CDRs. In order to eliminate the induction of a T-cell response to such epitopes, it may be desirable to eliminate these although this may reduce the binding affinity of the resultant antibody and thus any potential alteration of CDRs may need to be tested for any alteration of resultant antigen binding.

In one embodiment, the sequence of the deimmunized antibodies has been altered to remove one or more B-cell epitopes. For removal of human B-cell epitope the “veenering” or “resurfacing” method of Padian (Padian E. A., Molecular Immunology 28 489-498 (1991) and EP-A-0519596) may be utilized. There are two general steps in veneering a nonhuman antigen-binding site. Initially, the framework regions of the variable regions of an antibody molecule of interest are compared with corresponding framework region sequences of available human variable region databases. The most homologous human variable regions are then compared residue by residue to corresponding nonhuman amino acids. The residues in the non-human framework region that differ from the human counterpart are replaced by the residues present in the human moiety using recombinant techniques well known in the art. Residue switching is carried out with moieties that are at least partially exposed (solvent accessible), and care is exercised in the replacement of amino acid residues that may have a significant effect on the tertiary structure of variable region domains, such as proline, glycine and charged amino acids. The replacement of exterior residues generally has little, or no, effect on the interior domains, or on the interdomain contacts. (See, e.g., U.S. Pat. No. 6,797,492).

In this manner, the resultant “veenered” non-human antigen-binding sites are thus designed to retain the non-human CDR residues, the residues substantially adjacent to the CDRs, the residues identified as buried or mostly buried (solvent inaccessible), the residues believed to participate in non-covalent (e.g., electrostatic and hydrophobic) contacts between heavy and light chain domains, and the residues from conserved structural regions of the framework regions which are believed to influence the “canonical” tertiary structures of the CDR loops. These design criteria are then used to prepare recombinant nucleotide sequences that combine the CDRs of both the heavy and light chain of a non-human antigen-binding site to human-appearing framework regions that can be used to transfect mammalian cells for the expression of recombinant human antibodies that exhibit the antigen specificity of the non-human antibody molecule.

In one embodiment, regulatory T-cell epitopes are introduced into the antibody or antigen binding fragments. WO06/082406, which is hereby incorporated by reference, describes a method of producing antibodies wherein the antibody variable regions have been modified to introduce regulatory T-cell epitopes, which in turn stimulate CD4+CD25+ T-cells and induce the secretion of inhibitory cytokines, thereby reducing immunogenicity (see, e.g., Prakken B J, et al. Proc Natl Acad USA 94: 3284-3289 (1997)).

Construction of Antibodies or Antigen Binding Fragments

In general, the construction of the antibodies disclosed herein is achieved using recognized manipulations utilized in genetic engineering technology. For example, techniques for isolating DNA, making and selecting vectors for expressing the DNA, purifying and analyzing nucleic acids, specific methods for making recombinant vector DNA (e.g., PCR), cloning DNA with restriction enzymes, ligating DNA, introducing DNA, including vector DNA, into host cells by stable or transient means, culturing the host cells in selective or non-selective media, to select and maintain cells that express DNA, are generally known in the field.

Such deimmunized immunoglobulins can be produced using synthetic and/or recombinant nucleic acids to prepare genes (e.g., cDNA) encoding the desired deimmunized chain. For example, nucleic acid (e.g., DNA) sequences coding for deimmunized variable regions can be constructed using PCR mutagenesis methods to alter DNA sequences encoding a
deimmunized chain, such as a DNA template from a previously humanized variable region (see e.g., Kamman, M., et al., Nucl. Acids Res., 17: 5404 (1989); Sato, K., et al., Cancer Research, 53: 851-856 (1993); Daugherty, B. L. et al., Nucl. Acids Res., 19(9): 2471-2476 (1991); and Lewis, A. P. and J. S. Crowe, Gene, 101: 297-302 (1991)). Using these or other suitable methods, variants can also be readily produced. In one embodiment, cloned variable regions can be mutagenized, and sequences encoding variants with the desired specificity can be selected (e.g., from a phage library; see e.g., Krebber et al., U.S. Pat. No. 5,514,548; Hoogenboom et al., U.S. 93/06213, published Apr. 1, 1993).

Several possible vector systems are available for the expression of cloned heavy chain and light chain genes in mammalian cells. One class of vectors relies upon the integration of the desired gene sequences into the host cells genome. Cells which have stably integrated DNA can be selected by simultaneously introducing drug resistance genes such as E. coli gpt (Muttag, R. C. and Berg, P., Proc. Natl. Acad. Sci., USA, 78: 2072 (1981)) or Tn5 neo (Southern, P. J. and Berg, P., J. Mol. Appl. Genet., 1: 327 (1982)). The selectable marker gene can be either linked to the DNA gene sequences to be expressed, or introduced into the same cell by co-transfection (Wigler, M. et al., Cell, 16: 77 (1979)). A second class of vectors utilizes DNA elements which confer autonomously replicating capabilities to an extrachromosomal plasmid. These vectors can be derived from animal viruses, such as bovine papillomavirus (Sarver, N. et al., Proc. Natl. Acad. Sci., USA, 79: 7147 (1982)), polyoma virus (Deans, R. J. et al., Proc. Natl. Acad. Sci., USA, 81: 1292 (1984)), or SV40 virus (Lasky, M. and Botchan, M., Nature, 293: 79 (1981)).

Since an immunoglobulin cDNA is comprised only of sequences representing the mature mRNA encoding an antibody protein, additional gene expression elements regulating transcription of the gene and processing of the RNA are required for the synthesis of immunoglobulin mRNA. These elements may include splice signals, transcription promoters, including inducible promoters enhancers, and termination signals. cDNA expression vectors incorporating such elements include those described by Okayama, H. and Berg, P., Mol. Cell Biol., 3: 280 (1983); Cepko, C. L. et al., Cell, 37: 1053 (1984); and Kaufman, R. J., Proc. Natl. Acad. Sci., USA, 82: 689 (1985).

The variable sequence can, optionally, be fused to a human constant region, e.g., human IgG1 or .kappa. constant regions. The recombinant deimmunized antibody or antigen binding fragment can be transfected into a suitable host cell for expression, for example, NS0 or CHO cells, to produce complete recombinant antibodies.

VI. Diagnostic Applications

The antibodies and antigen binding fragments are useful in a variety of applications, including research, diagnostic and therapeutic applications. For instance, they can be used to isolate and/or purify receptor or portions thereof, and to study receptor structure (e.g., conformation) and function.

In certain aspects, the various antibodies disclosed can be used to detect or measure the expression of EPhB4 receptor, for example, on endothelial cells (e.g., venous endothelial cells), or on cells transfected with an EPhB4 receptor gene. Thus, they also have utility in applications such as cell sorting and imaging (e.g., flow cytometry, and fluorescence activated cell sorting), for diagnostic or research purposes.

In certain embodiments, the antibodies or antigen binding fragments can be labeled or unlabeled for diagnostic pur-
pria.te for binding of the antibody thereto, and antibody binding is monitored. Detection of the antibody, indicative of the formation of a complex between antibody and EphB4 or a portion thereof, indicates the presence of the receptor. Binding of antibody to the cell can be determined by standard methods, such as those described in the working examples. The method can be used to detect expression of EphB4 on cells from an individual. Optionally, a quantitative expression of EphB4 on the surface of endothelial cells can be evaluated, for instance, by flow cytometry, and the staining intensity can be correlated with disease susceptibility, progression or risk.

The antibody or antigen binding fragment may also be used in a method of detecting the susceptibility of a mammal to certain diseases. To illustrate, the method can be used to detect the susceptibility of a mammal to diseases which progress based on the amount of EphB4 present on cells and/or the number of EphB4-positive cells in a mammal. In one embodiment, the application provides a method of detecting susceptibility of a mammal to a tumor. In this embodiment, a sample to be tested is contacted with an antibody which binds to an EphB4 or portion thereof under conditions appropriate for binding of said antibody thereto, wherein the sample comprises cells which express EphB4 in normal individuals. The binding of antibody and/or amount of binding is detected, which indicates the susceptibility of the individual to a tumor, wherein higher levels of receptor correlate with increased susceptibility of the individual to a tumor. Applicants and other groups have found that expression of EphB4 has a correlation with tumor growth and progression. The antibodies disclosed can also be used to further elucidate the correlation of EphB4 expression with progression of angiogenesis-associated diseases in an individual.

IV. Therapeutic Applications

In certain embodiments, the present application provides methods of inhibiting angiogenesis and methods of treating angiogenesis-associated diseases. In some embodiments the application provides methods for promoting apoptosis. In other embodiments, the present application provides methods of inhibiting or reducing tumor growth and methods of treating an individual suffering from cancer. These methods involve administering to the individual a therapeutically effective amount of a deimmunized antibody or antigen binding fragment as described above. These methods are particularly aimed at therapeutic and prophylactic treatments of animals, and more particularly, humans. In one embodiment the antibody or antigen binding fragment used in the methods is less immunogenic when administered to a human subject than mouse monoclonal #47. In another embodiment the antibody or antigen binding fragment used in the method is less immunogenic when administered to a human subject than mouse monoclonal #131.

The present application also provides for pharmaceutical compositions useful in treating angiogenesis-associated diseases. In some embodiments the pharmaceutical composition comprises an antibody or antigen binding fragment described herein and an acceptable pharmaceutical carrier.

The present application provides for a method of promoting apoptosis comprising contacting cells with an effective amount of a deimmunized antibody or antigen binding fragment. In some embodiments, the cells are endothelial cells. The present application provides for a method of inhibiting angiogenesis comprising contacting endothelial cells with an effective amount of a deimmunized antibody or antigen binding fragment. In certain embodiments, said angiogenesis is induced by cancer cells. The antibody or antigen binding fragment may contact endothelial cells in vitro, ex vivo or in vivo (for example, in a subject). In still another embodiment, the antibodies inhibit the angiogenesis of cancer cells, such as for example, by at least 10%, at least 25%, at least 50%, at least 75%, or at least 90%. The inhibition of angiogenesis can be examined via in vitro cell-based assays known in the art, such as the endothelial cell tube formation assay, or in vivo animal model assays known in the art.

As described herein, angiogenesis-associated diseases include, but are not limited to, angiogenesis-dependent cancer, including, for example, solid tumors, blood born tumors such as leukemias, and tumor metastases; benign tumors, for example hemangiomas, acoustic neuromas, neurofibromas, trachomas, and pyogenic granulomas; inflammatory disorders such as immune and non-immune inflammation; chronic articular rheumatism and psoriasis; ocular angiogenic diseases, for example, diabetic retinopathy, retinopathy of prematurity, macular degeneration, corneal graft rejection, neovascular glaucoma, retrolental fibroplasia, ruberosis; Osler-Webber Syndrome; myocardial angiogenesis; plaque neovascularization; telangiectasia; hemophilic joints; angiofibroma; and wound granulation and wound healing; telangiectasia psoriasis scleroderma, pyogenic granuloma, coronary collaterals, ischemic limb angiogenesis, corneal diseases, ruberosis, arthritis, diabetic neovascularization, fractures, vasculogenesis, hematopoeisis.

It is understood that methods and compositions disclosed are also useful for treating any angiogenesis-independent cancers (tumors). As used herein, the term “angiogenesis-independent cancer” refers to a cancer (tumor) where there is no or little neovascularization in the tumor tissue.

In particular, antibody therapeutic agents disclosed are useful for treating or preventing a cancer (tumor), including, but not limited to, colon carcinoma, breast cancer, mesothelioma, prostate cancer, bladder cancer, squamous cell carcinoma of the head and neck (HNSCC), Kaposi sarcoma, ovarian cancer, and leukemia.

The present application provides for a method of inhibiting the growth of cancer cells in a subject comprising administering an effective amount of a deimmunized antibody or antigen binding fragment into the subject. The modulation may reduce or prevent the growth of the cancer cells of said subject, such as for example, by at least 10%, at least 25%, at least 50%, at least 75%, or at least 90%. As a result, where the cancer is a solid tumor, the modulation may reduce the size of the solid tumor by at least 10%, at least 25%, at least 50%, at least 75%, or at least 90%.

The inhibition of the cancer cell proliferation can be measured by cell-based assays, such as bromodeoxyuridine (BrdU) incorporation (Hoshino et al., Int. J. Cancer 38, 369 (1986); Campa et al., J. Immunol. Meth. 107:79 (1988)); [1H]thymidine incorporation (Chen, J., Oncogene 13:1395-403 (1996); Jeoung, J., J. Biol. Chem. 270:18367-73 (1995); the dye Alamar Blue (available from Biosource International) (Voytk-Harbin et al., In Vitro Cell Dev Biol Anim 34:239-46 (1998)). The anchorage independent growth of cancer cells is assessed by colony formation assay in soft agar, such as by counting the number of cancer cell colonies formed on top of the soft agar (see Examples and Sambrook et al., Molecular Cloning, Cold Spring Harbor, 1989).

The inhibition of cancer cell growth in a subject may be assessed by monitoring the cancer growth in a subject, for example in an animal model or in human subjects. One exemplary monitoring method is tumorigenicity assays. In one example, a xenograft comprises human cells from a pre-existing tumor or from a tumor cell line. Tumor xenograft assays are known in the art and described herein (see, e.g.,
In certain embodiments, the subject methods disclosed can be used alone. Alternatively, the subject methods may be used in combination with other conventional anti-cancer therapeutic approaches directed to treatment or prevention of proliferative disorders (e.g., tumor). For example, such methods can be used in prophylactic cancer prevention, prevention of cancer recurrence and metastases after surgery, and as an adjuvant of other conventional cancer therapy. The present application recognizes that the effectiveness of conventional cancer therapies (e.g., chemotherapy, radiation therapy, phototherapy, immunotherapy, and surgery) can be enhanced through the use of the antibody or antigen binding fragment.

A wide array of conventional compounds have been shown to have anti-neoplastic activities. These compounds have been used as pharmaceutical agents in chemotherapy to shrink solid tumors, prevent metastases and further growth, or decrease the number of malignant T-cells in leukemic or bone marrow malignancies. Although chemotherapy has been effective in treating various types of malignancies, many anti-neoplastic compounds induce undesirable side effects. It has been shown that when two or more different treatments are combined, the treatments may work synergistically and allow reduction of dosage of each of the treatments, thereby reducing the detrimental side effects exerted by each compound at higher dosages. In other instances, malignancies that are refractory to a treatment may respond to a combination therapy of two or more different treatments.

When the antibody or antigen binding fragment disclosed herein is administered in combination with another conventional anti-neoplastic agent, either concomitantly or sequentially, such antibody or antigen binding fragment may enhance the therapeutic effect of the anti-neoplastic agent or overcome cellular resistance to such anti-neoplastic agent. This allows decrease of dosage of an anti-neoplastic agent, thereby reducing the undesirable side effects, or restores the effectiveness of an anti-neoplastic agent in resistant T-cells.

Chemical compounds that may be used for combinatory anti-tumor therapy include, merely to illustrate: aminothiophendimide, amsacrine, anastrozole, asparaginase, bex, bicalutamide, bleomycin, busulfan, busulphan, camptothecin, cephalosporine, carboplatin, carmustine, chlorambucil, cisplatin, cloradine, clodronate, colchicine, cyclophosphamide, cyproterone, cytarabine, dacarbazine, daunomycin, danrubicin, dienestrol, doxilyslbistrol, docetaxel, doxorubicin, epirubicin, estradiol, estramustine, etoposide, exemestane, filgrastim, fludarabine, fludrocortisone, fluorouracil, fluroxymesterone, flutamide, gemicitabine, genistein, goserelin, hydroxyurea, idarubicin, ifosfamide, imatinib, interferon, irinotecan, irinotecan, leucovorin, leuprolide, levamisole, lomustine, melphalan, medroxyprogesterone, mephalan, mercuripiperazine, mesna, methotrexate, mitomycin, mitotane, mitoxantrone, nilotamide, nocodazole, octreotide, oxaliplatin, paclitaxel, pamidronate, pentostatin, picamycin, porfimer, procarbazine, raltitrexed, rituximab, streptozocin, suramin, tamoxifen, temozolomide, teniposide, testostereone, thioguanine, thiotepa, titanocene dichloride, topectane, trastuzumab, treotinin, vinblastine, vincristine, vindesine, and vinorelbine.

These chemotherapeutic anti-tumor compounds may be categorized by their mechanism of action into, for example, following groups: anti-metabolites/anti-cancer agents, such as pyrimidine analogs (5-fluorouracil, fluoxuridine, capcetabine, gemcitabine and cytarabine) and purine analogs, folate antagonists and related inhibitors (mercaptopturine, thioguanine, pentostatin and 2-chloro deoxyadenosine (cladribine)); antiproiferative/antiimmune agents including natural products such as vinca alkaloids (vinblastine, vincristine, and vinorelbine), microtubule disruptors such as taxane (paclitaxel, docetaxel), vincristin, vinblastin, nocodazole, epothilones and navelbine, epipodophyllotoxins (etoposide, teniposide), DNA damaging agents (actinomycin, amsacrine, anthracyclines, bleomycin, busulfan, camptothecin, carboplatin, chlorambucil, cisplatin, cyclophosphamide, cytoxan, daunomycin, doxorubicin, doxorubicin, epirubicin, hexamethylmelamine oxalplatin, ifosfamide, melphalan, mercuriophosphate, mitomycin, mitozantronate, nitrosourea, plicamycin, procarbazine. TAXOL™, taxotere, teniposide, triethylenethiophosphoramide and etoposide (VP16)); antibiotics such as dactinomycin (actinomycin D), daunorubicin, doxorubicin (adriamycin), idarubicin, anturacelines, mitoxantrone, bleomycins, plicamycin (mithramycin) and mitomycin; enzymes (L-asparaginase which systemically metabolizes L-asparagine and deprives cells which do not have the capacity to synthesize their own asparagine); antitumor agents; antiproliferative/antiimmune alkylating agents such as nitrogen mustards (melcuriophosphate, cyclophosphamide and analogs, melphalan, chlorambucil), ethylcellulose and methylnalamines (hexamethylmelamine and thiopeta), alkyl sulfonates-busulfan, nitrososemic (camustine (BCNU) and analogs, streptozocin), trazenesdarcarbazaine (DTIC); antiproiferative/antiimmune antitumor molecules such as folic acid analogs (methotrexate); platinum coordination complexes (cisplatin, carboplatin), procarbazine, hydroxyurea, mitotane, aminoglutethimide; hormones, hormones analogs (estrogen, tamoxifen, goserelin, bicalutamidine, nilotamide) and aromatase inhibitors (letrazole, anastrozole); anticoagulants (heparin, synthetic heparin salts and other inhibitors of thrombin); fibrolytic agents (such as tissue plasminogen activator, streptokinase and urokinase), aspirin, dipyridamole, ticlopidine, clopidogrel, abciximab; antimitotig agents; antisecretory agents (brevedin); immunosuppressives (cyclosporine, tacrolimus (FX-506), sirolimus (rapumycin), azathiaprine, mycophenolate mofetil); antiangiogenic compounds (1NP-470, genisten) and growth factor inhibitors (vascular endothelial growth factor (VEGF) inhibitors, fibroblast growth factor (FGF) inhibitors); angiotensin receptor blocker; nitric oxide donors; anti-sense oligonucleotides; antibodies (trastuzumab); cell cycle inhibitors and differentiation inducers (tretinoin); mor inhibitors; topoisomerase inhibitors (doxorubicin (adriamycin), amsacrine, camptothecin, daunorubicin, daunomycin, eniposide, epirubicin, etoposide, idarubicin and mitoxantrone, topotecan, irinotecan), corticosteroids (cortisone, dexamethasone, hydrocortisone, methylprednisolone, prednisolone, and pren-
isolone); growth factor signal transduction kinase inhibitors; mitochondrial dysfunction inducers and caspase activators; and chromatin disruptors.

In certain embodiments, pharmaceutical compounds that may be used for combinatory anti-angiogenesis therapy include: (1) inhibitors of release of "angiogenic molecules," such as bFGF (basic fibroblast growth factor); (2) neutralizers of angiogenic molecules, such as an anti-bFGF antibodies; and (3) inhibitors of endothelial cell response to angiogenic stimuli, including collagenase inhibitor, basement membrane turnover inhibitors, angiostatic steroids, fungal-derived angiogenesis inhibitors, platelet factor 4, thrombospondin, arthritis drugs such as D-penicillamine and gold thiomale, vitamin D3 analogs, alpha-interferon, and the like. For additional proposed inhibitors of angiogenesis, see Blood et al., Bioch. Biophys. Acta., 1032:89-118 (1990), Moses et al., Science, 248:1408-1410 (1990), Ingbir et al., J. Lab. Invest., 59:44-51 (1988), and U.S. Pat. Nos. 5,092,885, 5,112,946, 5,192,744, 5,202,352, and 6572356. In addition, there are a wide variety of compounds that can be used to inhibit angiogenesis, for example, peptides or agents that block the VEGF-mediated angiogenesis pathway, endostatin protein or derivatives, lysine binding fragments of angiotatin, melanin or melanin-promoting compounds, plasminogen fragments (e.g., Kringles 1-3 of plasminogen), tropin subunits, antagonists of vitronectin α,β, peptides derived from Saposin B, antibiotics or analogs (e.g., tetracycline, or neomycin), dienogest-containing compositions, compounds comprising a MetAP-2 inhibitor core coupled to a peptide, the compound EM-138, chalone and its analogs, and masaladase inhibitors. See, for example, U.S. Pat. Nos. 6,359,716, 6,462,075, 6,465,431, 6,475,784, 6,482,802, 6,482,810, 6,500,431, 6,500,924, 6,518,298, 6,521,439, 6,525,019, 6,538,103, 6,544,758, 6,544,947, 6,548,477, 6,559,126, and 6,569,845.

Depending on the nature of the combinatory therapy, administration of the EphB4 deimmunized antibody or antigen binding fragment may be continued while the other therapy is being administered and/or thereafter. Administration of the EphB4 deimmunized antibody or antigen binding fragment may be repeated, in a single dose, or in multiple doses. In some instances, administration of the EphB4 deimmunized antibody or antigen binding fragment is commenced at least several days prior to the conventional therapy, while in other instances, administration is begun either immediately before or at the time of the administration of the conventional therapy.

VIII. Modes of Administration and Formulations

In certain embodiments, the EphB4 deimmunized antibody or antigen binding fragment is formulated with a pharmaceutically acceptable carrier. Such antibody or antigen binding fragment can be administered alone or as a component of a pharmaceutical formulation (composition). The antibody or antigen binding fragment may be formulated for administration in any convenient way for use in human or veterinary medicine. Wetting agents, emulsifiers and lubricants, such as sodium lauryl sulfate and magnesium stearate, as well as coloring agents, release agents, coating agents, sweetening, flavoring and perfuming agents, preservatives and antioxidants can also be present in the compositions.

Formulations of the EphB4 deimmunized antibody or antigen binding fragment include those suitable for oral/nasal, topical, parenteral, rectal, and/or intravaginal administration. The formulations may conveniently be presented in unit dosage form and may be prepared by any methods well known in the art of pharmacy. The amount of active ingredient which can be combined with a carrier material to produce a single dosage form will vary depending upon the host being treated, the particular mode of administration. The amount of active ingredient which can be combined with a carrier material to produce a single dosage form will generally be that amount of the compound which produces a therapeutic effect.

In certain embodiments, methods of preparing these formulations or compositions include combining another type of anti-tumor or anti-angiogenesis therapeutic agent and a carrier and, optionally, one or more accessory ingredients. In general, the formulations can be prepared with a liquid carrier, or a finely divided solid carrier, or both, and then, if necessary, shaping the product.

Formulations for oral administration may be in the form of capsules, cachets, pills, tablets, lozenges (using a flavored basis, usually sucrose and acacia or tragacanth), powders, granules, or as a solution or suspension in an aqueous or non-aqueous liquid, or as a oil-in-water or water-in-oil liquid emulsion, or as an elixir or syrup, or as pastilles (using an inert base, such as gelatin and glycerin, or sucrose and acacia) and/or as mouth washes and the like, each containing a predetermined amount of an EphB4 deimmunized antibody or antigen binding fragment as an active ingredient.

In solid dosage forms for oral administration (capsules, tablets, pills, dragees, powders, granules, and the like), one or more EphB4 deimmunized antibody or antigen binding fragment may be mixed with one or more pharmaceutically acceptable carriers, such as sodium citrate or dicalcium phosphate, and/or any of the following: (1) fillers or extenders, such as starches, lactose, sucrose, glucose, mannitol, and/or silicic acid; (2) binders, such as, for example, carboxymethyl cellulose, alginates, gelatin, polyvinyl pyroli dine, sucrose, and/or acacia; (3) humectants, such as glycerol; (4) disintegrating agents, such as agar-agar, calcium carbonate, potato or tapioca starch, alginic acid, certain silicates, and sodium carbonate; (5) solution retarding agents, such as paraffin; (6) absorption accelerators, such as quaternary ammonium compounds; (7) wetting agents, such as, for example, cetlyl alcohol and glycerol monostearate; (8) absorbents, such as kaolin and bentonite clay; (9) lubricants, such as talc, calcium stearate, magnesium stearate, solid polyethylene glycols, sodium lauryl sulfate, and mixtures thereof; and (10) coloring agents. In the case of capsules, tablets and pills, the pharmaceutical compositions may also comprise buffering agents. Solid compositions of a similar type may also be employed as fillers in soft and hard-filled gelatin capsules using such excipients as lactose or milk sugars, as well as high molecular weight polyethylene glycols and the like.

Liquid dosage forms for oral administration include pharmaceutically acceptable emulsions, microemulsions, solutions, suspensions, syrups, and elixirs. In addition to the active ingredient, the liquid dosage forms may contain inert diluents commonly used in the art, such as water or other solvents, solubilizing agents and emulsifiers, such as ethyl alcohol, isopropyl alcohol, ethyl carbonate, ethyl acetate, benzyl alcohol, benzyl benzoate, propylene glycol, 1,3-butanediol glycol, oils (in particular, cottonseed, groundnut, corn, germ, olive, castor, and sesame oils), glycerol, triarylurea alcohol, polyethylene glycols and fatty acid esters of sorbitan, and mixtures thereof. Besides inert diluents, the oral compositions can also include adjuvants such as wetting agents, emulsifying and suspending agents, sweetening, flavoring, coloring, perfuming, and preservative agents.

Suspensions, in addition to the active compounds, may contain suspending agents such as ethoxylated isostearate alcohols, polyoxyethylene sorbitol, and sorbitan esters,
microcrystalline cellulose, aluminum metahydroxide, bentonite, agar-agar and tragacanth, and mixtures thereof.

In particular, the disclosed methods can be administered topically, either to skin or to mucosal membranes such as those on the cervix and vagina. This offers the greatest opportunity for direct delivery to tumor with the lowest chance of inducing side effects. The topical formulations may further include one or more of the wide variety of agents known to be effective as skin or stratum corneum penetration enhancers. Examples of these are 2-pyrrolidone, N-methyl-2-pyrrolidone, dimethylacetamide, dimethylformamide, propylene glycol, methyl or isopropyl alcohol, dimethyl sulfoxide, and azone. Additional agents may further be included to make the formulation cosmetically acceptable. Examples of these are fats, waxes, oils, dyes, fragrances, preservatives, stabilizers, and surface active agents. Keratolytic agents such as those known in the art may also be included. Examples are salicylic acid and sulfur.

Dosage forms for the topical or transdermal administration include powders, sprays, ointments, pastes, creams, lotions, gels, solutions, patches, and inhalants. The EphB4 deimmunized antibody or antigen binding fragment may be mixed under sterile conditions with a pharmaceutically acceptable carrier, and with any preservatives, buffers, or propellants which may be required. The ointments, pastes, creams and gels may contain, in addition to a subject polypeptide agent, excipients, such as animal and vegetable fats, oils, waxes, paraffins, starch, tragacanth, cellulose derivatives, polyethylene glycols, silicones, bentonites, silicic acid, talc and zinc oxide, or mixtures thereof.

Powders and sprays can contain, in addition to a subject polypeptide therapeutic agent, excipients such as lactose, talc, silicic acid, aluminum hydroxide, calcium silicates, and polyamide powder, or mixtures of these substances. Sprays can additionally contain customary propellants, such as chlorofluorohydrocarbons and volatile unsubstituted hydrocarbons, such as butane and propane.

Pharmaceutical compositions suitable for parenteral administration may comprise one or more EphB4 deimmunized antibodies and antigen binding fragments in combination with one or more pharmaceutically acceptable sterile isotonic aqueous or nonaqueous solutions, suspensions, emulsions, or sterile powders which may be reconstituted into sterile injectable solutions or suspensions just prior to use, which may contain antioxidants, buffers, bacteriostats, solutes which render the formulation isotonic with the blood of the intended recipient or suspending or thickening agents. Examples of suitable aqueous and nonaqueous carriers which may be employed in the disclosed pharmaceutical compositions include water, ethanol, polyols (such as glycerol, propylene glycol, polyethylene glycol, and the like), and suitable mixtures thereof, vegetable oils, such as olive oil, and injectable organic esters, such as ethyl oleate. Proper fluidity can be maintained, for example, by the use of coating materials, such as lecithin, by the maintenance of the required particle size in the case of dispersions, and by the use of surfactants.

These compositions may also contain adjuvants, such as preservatives, wetting agents, emulsifying agents and dispersing agents. Prevention of the action of microorganisms may be ensured by the inclusion of various antibacterial and antifungal agents, for example, paraben, chlorobutanol, phenol sorbic acid, and the like. It may also be desirable to include isotonic agents, such as sugars, sodium chloride, and the like into the compositions. In addition, prolonged absorption of the injectable pharmaceutical form may be brought about by the inclusion of agents which delay absorption, such as aluminum monostearate and gelatin.

Injectable depot forms are made by forming microencapsule matrices of one or more the EphB4 deimmunized antibodies and antigen binding fragments in biodegradable polymers such as poly lactate-polyglycolide. Depending on the ratio of drug to polymer, and the nature of the particular polymer employed, the rate of drug release can be controlled. Examples of other biodegradable polymers include poly (orthoesters) and poly (anhydrides). Depot injectable formulations are also prepared by entrapping the drug in liposomes or microemulsions which are compatible with body tissue.

Formulations for intravaginal or rectally administration may be presented as a suppository, which may be prepared by mixing one or more of the disclosed compounds with one or more suitable nonirritating excipients or carriers comprising, for example, cocoa butter, glycerol, a suppository wax or a salicylate, and which is solid at room temperature, but liquid at body temperature and, therefore, will melt in the rectum or vaginal cavity and release the active compound.

Pharmaceutical compositions suitable for use include compositions wherein one or more of the EphB4 deimmunized antibodies and antigen binding fragments are contained in an amount effective to achieve their intended purpose. More specifically, a therapeutically effective amount means an amount of antibody effective to prevent, alleviate or ameliorate symptoms of disease or prolong the survival of the subject being treated. Determination of a therapeutically effective amount is well within the capability of those skilled in the art, especially in light of the detailed disclosure provided herein. Therapeutically effective dosages may be determined by using in vitro and in vivo methods.

EXEMPLIFICATION

Example 1

Generation of Deimmunized Antibodies

Mouse monoclonal antibodies #47 and #131 were prepared as described in US application 2005/0249736. Briefly, anti-EphB4 monoclonal antibodies were raised in mice against the extracellular domain (ECD) of EphB4. The ECD of EphB4 was cloned into pGEX-4T-1 to generate GST fused ECD (GST-ECD). EphB4ECD expressed as a GST fusion protein in BL21 E. coli was purified by affinity chromatography and the GST domain was cleaved by thrombin. Monoclonal antibody was generated by standard protocols and purified from hybridoma supernatants by Protein A chromatography. The sensitivity and specificity of the antibody was confirmed by Western blot with whole cell lysate of 293 cells stably transfected with EphB4. The sequences for #47 and #131 are provided in the sequence listing.

A structural model of the murine sequences was generated using Swiss Pdb in order to identify amino acids involved in antigen binding affinity. Only the Kabat and Chothia CDRs were identified.

The murine sequences were then analyzed in silico in order to identify MHC class II binding epitopes. In parallel, the closest human germline antibody gene was identified for each individual murine framework. Potential epitopes were eliminated by making a substitution in the murine sequence. The substituted residue was obtained from the homologous human germline gene. A series of variants, usually 4 or 5, was generated to test the effect of various substitutions on antigen binding affinity.
The variant variable regions were synthesized from overlapping oligonucleotides using standard methods. The variable regions were then cloned and expressed as human IgG1/kappa antibodies. All combinations of heavy chain and light chain variants were generated for #47 and #131 independently. The combinations were transiently transfected into CHO-K1 cells and the supernatants were harvested to test for activity.

Table 1 depicts the SEQ ID Nos for the parental and deimmunized variable regions. The protein and nucleotide sequences for the heavy (H) and light (K) chain variable regions (V) of the deimmunized variants are listed. The protein sequence of the variable regions of the mouse monoclonal #47 and #131 (m47, m131) antibodies as well as the individual CDRs for both the heavy (H) and light (K) chain are also listed. FIG. 2A-D also depicts an alignment of the variable regions of the mouse monoclonal parental antibody against the deimmunized variants.

### Table 1

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### Example 2

**Characterization of EphB4 Binding**

The binding affinity for several of the deimmunized antibodies was determined using a standard sandwich ELISA binding assay. Briefly, plates were coated with NeutrAvidin at 2 μg/ml, followed by the addition of 1 μg/ml of biotin-labeled soluble EphB4-HSA fusion protein. Serially diluted (1:3) deimmunized #131 or #47 variants were then added, starting at a concentration of 1 μg/ml. Detection was performed using goat anti-human-Fc-HRP antibody. The data were averaged from duplicates. FIGS. 3 and 4 show graphs of the apparent binding affinities for a subset of the disclosed deimmunized antibodies. Of the 4 deimmunized #47 variants, all show similar binding affinity to a chimeric #47, while one deimmunized antibody (SEQ ID NO:3/SEQ ID NO:8) shows an improvement in binding affinity. The deimmunized #131 variants also show a similar binding affinity when compared to a chimeric #131.

### Example 3

**EphB4 Degradation**

HT29 cells were treated with 10 mg/ml of the indicated monoclonal antibody (Mu—murine; Ch—chimeric and Del—deimmunized) for 6 h, followed by washing with cold PBS and direct lysis into SDS-buffer. The cell lysate was run on SDS gels and Western blots were performed using an anti-EphB4 primary antibody (FIG. 5).

### Example 4

**In Vivo Xenograft Assay**

In order to characterize the in vivo effect of the deimmunized antibodies, in vivo tumor xenograft assays were performed. Briefly, cells were propagated, collected by trypsin digestion and re-suspended in serum free medium. Approximately 2x10⁶ cells were injected in the flank of ten to twelve-week old, female Balb/c athylic mice, either SCID15 cells for a squamous cell carcinoma model or H29 cells for a colon cancer model. Tumor growth was measured three times a week and volume estimated as 0.52wa×wb², where a and b are the largest and smallest lengths of the palpable tumor. On day 4 after cell implantation, tumor volumes were calculated to ensure uniformity in size and animals were randomly divided into three groups (n=6 mice per group). Each group was administered three times a week intraperitoneal (i.p.) injection, 10 mg/kg of the test antibodies or vehicle alone (sterile normal saline, pH 7.4). Animals were sacrificed and tumors and normal organs harvested after four weeks. A portion of the tumors was fixed in formalin for paraffin-embedding and histologic analysis. The remaining tumor tissue and organs in each group were pooled and protein extracted. All procedures were approved by our Institutional Animal Care and Use Committee and performed in accordance with the Animal Welfare Act regulations. The following data (Tables 2 and 3) was collected from an in vivo squamous cell carcinoma xenograft assay. Tumor volume is expressed in mm³ and the day number corresponds to the number of days following the beginning of treatment. The parent mouse monoclonal antibody, #47 or #131, is compared to an exemplary deimmunized antibody. The control group was administered vehicle alone. Results are also depicted graphically in FIGS. 6a and 6b.

### Table 2

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Both the exemplary deimmunized #47 antibody and the exemplary deimmunized #131 antibody showed similar levels of tumor growth inhibition as the mouse monoclonal #47 and #131 antibody, respectively. This is in stark comparison to the control as well as to a different mouse monoclonal anti-EphB4 antibody #5L, described in US application 2003/0249736.

The following data (Table 4) was collected from a colon cancer xenograft model assay on day 14 of treatment. As
described above, the effect of treatment with either the mouse monoclonal antibody or a deimmunized variant is compared. Additionally, administration of IgG1 is also used as a control.

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From the above results, it is apparent that the disclosed deimmunized antibodies are effective in reducing tumor growth in at least two cancer xenograft models.

BRIEF DESCRIPTION OF SEQUENCES

SEQ ID NO:1-5 correspond to the amino acid sequences of heavy chain variable region deimmunized variants derived from mouse monoclonal antibody #47.

SEQ ID NO:6-9 correspond to the amino acid sequences of light chain variable region deimmunized variants derived from mouse monoclonal antibody #47.

SEQ ID NO:10-14 correspond to the amino acid sequences of heavy chain variable region deimmunized variants derived from mouse monoclonal antibody #131.

SEQ ID NO:15-18 correspond to the amino acid sequences of light chain variable region deimmunized variants derived from mouse monoclonal antibody #131.

SEQ ID NO:19-21 correspond to the amino acid sequences of heavy chain variable region deimmunized CDRs from mouse monoclonal antibody #47.

SEQ ID NO:22-24 correspond to the amino acid sequences of light chain variable region CDRs from mouse monoclonal antibody #47.

SEQ ID NO:25-27 correspond to the amino acid sequences of heavy chain variable region CDRs from mouse monoclonal antibody #131.

SEQ ID NO:28-30 correspond to the amino acid sequences of light chain variable region CDRs from mouse monoclonal antibody #131.

SEQ ID NO:31-35 correspond to the nucleic acid sequences of heavy chain variable region deimmunized variants derived from mouse monoclonal antibody #47.

SEQ ID NO:36-39 correspond to the nucleic acid sequences of light chain variable region deimmunized variants derived from mouse monoclonal antibody #47.

SEQ ID NO:40-44 correspond to the nucleic acid sequences of heavy chain variable region deimmunized variants derived from mouse monoclonal antibody #131.

SEQ ID NO:45-48 correspond to the nucleic acid sequences of light chain variable region deimmunized variants derived from mouse monoclonal antibody #131.

SEQ ID NO:49-52 correspond to the mouse monoclonal heavy and light chain variable region of antibody #47 and the mouse monoclonal heavy and light chain variable region of antibody #131, respectively.

SEQUENCE LISTING

SEQ ID NO:53 corresponds to the human EphB4 precursor protein.

SEQ ID NO:1: Heavy chain variable region deimmunized 47 variant 1

EQVLCQQGSEELKPGASVKIcekSCSAGETPTDYYVRKWQPGEGLEW1D
NHPKGQTYKQFKEGRATLTVDESTSTAYMELSLSREDSEAVYCRCGK
YGGTSQGYFDSWQGQTTYTVSS

SEQ ID NO:2: Heavy chain variable region deimmunized 47 variant 2

EQVLCQQGSEELKPGASVKIcekSCSAGETPTDYYVRKWQPGEGLEW1D
NHPKGQTYKQFKEGRATLTVDESTSTAYMELSLSREDSEAVYCRCGK
YGGTSQGYFDSWQGQTTYTVSS

SEQ ID NO:3: Heavy chain variable region deimmunized 47 variant 3

EQVLCQQGSEELKPGASVKIcekSCSAGETPTDYYVRKWQPGEGLEW1D
NHPKGQTYKQFKEGRATLTVDESTSTAYMELSLSREDSEAVYCRCGK
YGGTSQGYFDSWQGQTTYTVSS

SEQ ID NO:4: Heavy chain variable region deimmunized 47 variant 4

EQVLCQQGSEELKPGASVKIcekSCSAGETPTDYYVRKWQPGEGLEW1D
NHPKGQTYKQFKEGRATLTVDESTSTAYMELSLSREDSEAVYCRCGK
YGGTSQGYFDSWQGQTTYTVSS

SEQ ID NO:5: Heavy chain variable region deimmunized 47 variant 5

EQVLCQQGSEELKPGASVKIcekSCSAGETPTDYYVRKWQPGEGLEW1D
NHPKGQTYKQFKEGRATLTVDESTSTAYMELSLSREDSEAVYCRCGK
YGGTSQGYFDSWQGQTTYTVSS

SEQ ID NO:6: Light chain variable region deimmunized 47 variant 1

DIOMQSESSLASSLIEQILDOELCQSELENYADVQTCQQKPTLVPYD
ATVELADCEPFSRSQGSGDDQLQLQAEARRAYCQYTVSS1PWTFFQ
GTRKLEIK

SEQ ID NO:7: Light chain variable region deimmunized 47 variant 2

DIOMQSESSLASSLIEQILDOELCQSELENYADVQTCQQKPTLVPYD
ATVELADCEPFSRSQGSGDDQLQLQAEARRAYCQYTVSS1PWTFFQ
GTRKLEIK

SEQ ID NO:8: Light chain variable region deimmunized 47 variant 3

DIOMQSESSLASSLIEQILDOELCQSELENYADVQTCQQKPTLVPYD
ATVELADCEPFSRSQGSGDDQLQLQAEARRAYCQYTVSS1PWTFFQ
GTRKLEIK

SEQ ID NO:9: Light chain variable region deimmunized 47 variant 4

DIOMQSESSLASSLIEQILDOELCQSELENYADVQTCQQKPTLVPYD
ATVELADCEPFSRSQGSGDDQLQLQAEARRAYCQYTVSS1PWTFFQ
GTRKLEIK

SEQ ID NO:10: Heavy chain variable region deimmunized 131 variant 1

EQVLCQQGSEELKPGASVKIcekSCSAGETPTDYYVRKWQPGEGLEW1G
IGPRIGTNYNENFQKGRATLTDISTNTAYMELSLSREDSEAVYFCARSE
DSCQTVSYALDYWQGQTTYTVSS

SEQ ID NO:11: Heavy chain variable region deimmunized 131 variant 2

EQVLCQQGSEELKPGASVKIcekSCSAGETPTDYYVRKWQPGEGLEW1G
IGPRIGTNYNENFQKGRATLTDISTNTAYMELSLSREDSEAVYFCARSE
DSCQTVSYALDYWQGQTTYTVSS

SEQ ID NO:12: Heavy chain variable region deimmunized 131 variant 3

EQVLCQQGSEELKPGASVKIcekSCSAGETPTDYYVRKWQPGEGLEW1G
IGPRIGTNYNENFQKGRATLTDISTNTAYMELSLSREDSEAVYFCARSE
DSCQTVSYALDYWQGQTTYTVSS
SEQ ID NO:11: Human monoclonal antibody region
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QVQLVQGSASGVSASYFVPATDTPNDTVQYRQRKQEPDRGKRKQGI
G1PEIIYGTRIHVEKFWLRHITADDMMTACMLESLRGRGRTAVYSRASE
DYSVYVSDLDWYQQKLTVVSS

SEQ ID NO:14: Heavy chain variable region
denatured 1 variant 5
QVQLVQGSASGVSASYFVPATDTPNDTVQYRQRKQEPDRGKRKQGI
G1PEIIYGTRIHVEKFWLRHITADDMMTACMLESLRGRGRTAVYSRASE
DYSVYVSDLDWYQQKLTVVSS

SEQ ID NO:15: Light chain variable region
denatured 1 variant 1
NIVMTQPSLASLSPGERVTSCKASENVDTTVSWSYQPKDPQSPKLLVIY
GSMRGRYVPERQFSGSSATDFTLTISSLQAEVADYHHCQYYRFTYFFQ
GTVREIK

SEQ ID NO:16: Light chain variable region
denatured 1 variant 2
NIVMTQPSLASLSPGERVTSCKASENVDTTVSWSYQPKDPQSPKLLVIY
GSMRGRYVPERQFSGSSATDFTLTISSLQAEVADYHHCQYYRFTYFFQ
GTVREIK

SEQ ID NO:17: Light chain variable region
denatured 1 variant 3
NIVMTQPSLASLSPGERVTSCKASENVDTTVSWSYQPKDPQSPKLLVIY
GSMRGRYVPERQFSGSSATDFTLTISSLQAEVADYHHCQYYRFTYFFQ
GTVREIK

SEQ ID NO:18: Light chain variable region
denatured 1 variant 4
NIVMTQPSLASLSPGERVTSCKASENVDTTVSWSYQPKDPQSPKLLVIY
GSMRGRYVPERQFSGSSATDFTLTISSLQAEVADYHHCQYYRFTYFFQ
GTVREIK

SEQ ID NO:19: Mouse monoclonal antibody #47
heavy chain CDR1
DYWMN

SEQ ID NO:20: Mouse monoclonal antibody #47
heavy chain CDR2
DNHRHMQPSTQYKPF

SEQ ID NO:21: Mouse monoclonal antibody #47
heavy chain CDR3
GKYGTVSYGNTYDFV

SEQ ID NO:22: Mouse monoclonal antibody #47
light chain CDR1
RISDDNIDEYLA

SEQ ID NO:23: Mouse monoclonal antibody #47
light chain CDR2
DATVLAD

SEQ ID NO:24: Mouse monoclonal antibody #47
light chain CDR3
QVYS1PW

SEQ ID NO:25: Mouse monoclonal antibody #131
heavy chain CDR1
DYYIN

SEQ ID NO:26: Mouse monoclonal antibody #131
heavy chain CDR2
KIGFRTIGNYWNFK

SEQ ID NO:27: Mouse monoclonal antibody #131
heavy chain CDR3
SEDYYGYSVALDY

SEQ ID NO:28: Mouse monoclonal antibody #131
light chain CDR1
KAGFQDPVTTYV

SEQ ID NO:29: Mouse monoclonal antibody #131
light chain CDR2
GASNRTY
INCORPORATION BY REFERENCE

All publications and patents mentioned herein are hereby incorporated by reference in their entirety as if each indi-
vidual publication or patent was specifically and individually indicated to be incorporated by reference.

While specific embodiments of the subject invention have been discussed, the above specification is illustrative and not restrictive. Many variations of the invention will become apparent to those skilled in the art upon review of this specification and the claims below. The full scope of the invention should be determined by reference to the claims, along with their full scope of equivalents, and the specification, along with such variations.

SEQUENCE LISTING

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Tyr Met Asn Trp Val Lys Gin Ala His Gly Lys Gly Leu Glu Trp Ile
35   40   45
Gly Asp Asn Asn Pro Asn Gin Gly Thr Thr Tyr Thr Asn Gin Lys Phe
50   55   60
Lys Gly Arg Ala Thr Leu Thr Val Asp Lys Ser Thr Ser Thr Ala Tyr
65   70   75   80
Met Glu Leu Arg Ser Leu Arg Ser Glu Asp Ser Ala Val Tyr Tyr Cys
85   90   95
Ala Arg Gly Lys Tyr Tyr Gly Thr Ser Tyr Gly Trp Tyr Phe Asp Val
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Trp Gly Gin Gly Thr Val Thr Val Thr Val Ser Ser
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Ser Val Lys Ile Ser Cys Lys Ala Ser Gly Tyr Thr Phe Thr Asp Tyr
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Tyr Met Asn Trp Val Lys Gin Ala His Gly Lys Gly Leu Glu Trp Ile
35   40   45
Gly Asp Asn Asn Pro Asn Gin Gly Thr Thr Tyr Thr Asn Gin Lys Phe
50   55   60
Lys Gly Arg Ala Thr Leu Thr Val Asp Lys Ser Thr Ser Thr Ala Tyr
65   70   75   80
Met Glu Leu Ser Leu Arg Ser Glu Asp Ser Ala Val Tyr Tyr Cys
85   90   95
Ala Arg Gly Lys Tyr Tyr Gly Thr Ser Tyr Gly Trp Tyr Phe Asp Val
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35 40 45
Gly Asp Asn Asn Pro Asn Asn Gly Thr Thr Tyr Asn Gln Lys Phe
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Lys Gly Arg Ala Thr Leu Thr Val Asp Lys Ser Thr Ser Thr Ala Tyr
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Met Glu Leu Ser Ser Leu Arg Ser Glu Asp Thr Ala Val Tyr Tyr Cys
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Tyr Met Asn Trp Val Lys Gln Ala Pro Gly Lys Gly Leu Glu Trp Ile
35 40 45
Gly Asp Asn Asn Pro Asn Asn Gly Thr Thr Tyr Asn Gln Lys Phe
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Lys Gly Arg Ala Thr Leu Thr Val Asp Lys Ser Thr Ser Thr Ala Tyr
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Met Glu Leu Ser Ser Leu Arg Ser Glu Asp Thr Ala Val Tyr Tyr Cys
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**SEQ ID NO 8**

**LENGTH:** 107

**TYPE:** PRT

**ORGANISM:** Artificial Sequence

**FEATURE:**

**OTHER INFORMATION:** Description of Artificial Sequence: Synthetic polypeptide

**SEQUENCE:** 8

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A sp A rg V al T hr I le T hr C ys A rg I le S er A sp A sm I le A sp S er T yr
20       25     30
L eu A la T rp P he G ln G ln L ys P ro G ly L ys A la P ro L ys L eu L eu V al
35       40     45
T yr A sp A la T hr V al L eu A la A sp G ly V al P ro S er A rg P he S er G ly
50       55     60
S er G ly S er G ly T hr A sp T yr T hr L eu T hr I le A sm S er L eu G ln A la
65       70     75     80
G lu A sp A la A la T yr T yr C ys G ln V al T yr T yr S er I le P ro T rp
85       90     95
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**SEQ ID NO 9**

**LENGTH:** 107

**TYPE:** PRT

**ORGANISM:** Artificial Sequence

**FEATURE:**

**OTHER INFORMATION:** Description of Artificial Sequence: Synthetic polypeptide

**SEQUENCE:** 9

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A sp A rg V al T hr I le T hr C ys A rg I le S er A sp A sm I le A sp S er T yr
20       25     30
L eu A la T rp T yr G ln G ln L ys P ro G ly L ys A la P ro L ys L eu L eu V al
35       40     45
T yr A sp A la T hr V al L eu A la A sp G ly V al P ro S er A rg P he S er G ly
50       55     60
S er G ly S er G ly T hr A sp T yr T hr L eu T hr I le A sm S er L eu G ln A la
65       70     75     80
G lu A sp A la A la T yr T yr C ys G ln V al T yr T yr S er I le P ro T rp
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**SEQ ID NO 13**

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Tyr Ile Asn Trp Val Lys Glu Ala Pro Gly Glu Gly Leu Glu Trp Ile
35  40    45
Gly Lys Ile Gly Pro Arg Ile Gly Thr Asn Tyr Tyr Asn Gly Asn Phe
50  55    60
Lys Gly Arg Ala Thr Leu Thr Ala Asp Ile Ser Thr Asn Thr Ala Tyr
65  70    75   80
Met Glu Leu Ser Ser Leu Arg Ser Glu Asp Ser Ala Val Tyr Phe Cys
85  90    95
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Trp Gly Glu Gly Thr Ser Val Thr Val Ser Ser
115 120

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Ser Val Lys Ile Ser Cys Lys Ala Ser Gly Tyr Thr Phe Thr Asp Tyr
20  25    30
Tyr Ile Asn Trp Val Lys Glu Ala Pro Gly Glu Gly Leu Glu Trp Ile
35  40    45
Gly Lys Ile Gly Pro Arg Ile Gly Thr Asn Tyr Tyr Asn Gly Asn Phe
50  55    60
Lys Gly Arg Ala Thr Leu Thr Ala Asp Ile Ser Thr Asn Thr Ala Tyr
65  70    75   80
Met Glu Leu Ser Ser Leu Arg Ser Glu Asp Ser Ala Val Tyr Phe Cys
85  90    95
Ala Arg Ser Glu Asp Tyr Ser Gly Tyr Val Ser Tyr Ala Leu Asp Tyr
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115 120

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polypeptide

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Tyr Ile Asn Trp Val Lys Gln Ala Pro Gly Glu Gly Leu Glu Trp Ile
35 40 45

Gly Lys Ile Gly Pro Arg Ile Gly Thr Asn Tyr Tyr Asn Glu Asn Phe
50 55 60

Lys Gly Arg Val Thr Leu Thr Ala Asp Ile Ser Thr Asn Thr Ala Tyr
65 70 75 80

Met Glu Leu Ser Ser Leu Arg Ser Glu Asp Thr Ala Val Tyr Tyr Cys
85 90 95

Ala Arg Ser Glu Asp Tyr Ser Gly Tyr Val Ser Tyr Ala Leu Asp Tyr
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Trp Gly Gln Gly Thr Leu Val Thr Val Ser Ser
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20 25 30

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35 40 45

Gly Lys Ile Gly Pro Arg Ile Gly Thr Asn Tyr Tyr Asn Glu Asn Phe
50 55 60

Lys Gly Arg Val Thr Leu Thr Ala Asp Ile Ser Thr Asn Thr Ala Tyr
65 70 75 80

Met Glu Leu Ser Ser Leu Arg Ser Glu Asp Thr Ala Val Tyr Tyr Cys
85 90 95

Ala Arg Ser Glu Asp Tyr Ser Gly Tyr Val Ser Tyr Ala Leu Asp Tyr
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20 25 30
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Lys Gly Arg Val Thr Leu Thr Ala Asp Ile Ser Thr Ser Thr Ala Tyr
   65  70  75  80
Met Glu Leu Ser Ser Leu Arg Ser Glu Asp Thr Ala Val Tyr Tyr Cys
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Val Ser Trp Tyr Gln Gln Pro Asp Glu Ser Pro Leu Leu Ile
  35  40  45
Tyr Gly Ala Ser Asn Arg Tyr Thr Gly Val Pro Asp Arg Phe Thr Gly
  50  55  60
Ser Gly Ser Ala Thr Asp Phe Thr Leu Thr Ile Ser Ser Leu Gln Ala
  65  70  75  80
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Val Ser Trp Tyr Gln Gln Pro Asp Glu Ser Pro Leu Leu Ile
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Tyr Gly Ala Ser Asn Arg Tyr Thr Gly Val Pro Asp Arg Phe Thr Gly
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Ser Gly Ser Ala Thr Asp Phe Thr Leu Thr Ile Ser Ser Leu Gln Ala
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Glu Asp Val Ala Asp Tyr His Cys Gly Gin Thr Tyr Arg Tyr Pro Phe
  85  90  95

Thr Phe Gly Gln Gly Thr Lys Val Glu Ile Lys  
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| SEQ ID NO | 17 |
| LENGTH:  | 107 |
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| ORGANISM: Artificial Sequence |

**FEATURES: Description of Artificial Sequence: Synthetic polypeptide**

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| SEQ ID NO | 18 |
| LENGTH:  | 107 |
| TYPE:    | PRT |
| ORGANISM: Artificial Sequence |

**FEATURES: Description of Artificial Sequence: Synthetic polypeptide**

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| LENGTH:  | 5 |
| TYPE:    | PRT |
| ORGANISM: Mus sp. |

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<212> TYPE: PRT
<213> ORGANISM: Mus sp.

<400> SEQUENCE: 21

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<210> SEQ ID NO 22
<211> LENGTH: 11
<212> TYPE: PRT
<213> ORGANISM: Mus sp.

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<210> SEQ ID NO 23
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<212> TYPE: PRT
<213> ORGANISM: Mus sp.

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<210> SEQ ID NO 24
<211> LENGTH: 9
<212> TYPE: PRT
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<400> SEQUENCE: 24

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<210> SEQ ID NO 25
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<212> TYPE: PRT
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<212> TYPE: PRT
<213> ORGANISM: Mus sp.

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<212> TYPE: PRT
<213> ORGANISM: Mus sp.

<400> SEQUENCE: 28

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<212> TYPE: PRT
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aaaacagagt tcaagggcag ggccacattg actgtagaca gttccaccaag cccagctccc 240
atggagcttc gcaagcctgag atctggagac tctgcaagtct attacttgtgc aaagggaaa 300
tactagag 360
tctctctca 369

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gagatgtctg cgagatatta ctagtcaaggt tattatagta ttccgtggac gttcggtcaaa 300
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ggaaagagtct taagctctct ggtctatgtg gcacactgtct tagcagatgg tgtgcctca 180
agtgatgcat gacagtggagc aggcacacag tatactctca gcataaacag cctgcaagtct 240
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polynucleotide

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cagggagc gccgtgttgg gattggtcag atggctcttc gattggttgc taacttac  180
aatgaaacct tcaagggaca gtcgaactgc agtcgaaga cttccaccaaa cacagcctac  240
atggagcttt cctctcgtttg atcttgagat cccgtgtctt attactgtgc aagatctgg  300
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cagggagc gccgtgttgg gattggtcag atggctcttc gattggttgc taacttac  180
aatgaaacct tcaagggaca gtcgaactgc agtcgaaga cttccaccaaa cacagcctac  240
atggagcttt cctctcgtttg atcttgagat cccgtgtctt attactgtgc aagatctgg  300
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cagggagc gccgtgttgg gattggtcag atggctcttc gattggttgc taacttac  180
aatgaaacct tcaagggaca gtcgaactgc agtcgaaga cttccaccaaa cacagcctac  240
atggagcttt cctctcgtttg atcttgagat cccgtgtctt attactgtgc aagatctgg  300
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gttcctca  369

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gacccagcttc cttaattgttg aatTTacggg gcatccaaac ggtacaacgga agttcctgat 180
cgttcacag gcagttgtggtat gcaacagat ttcaacctca ctatcagcag tcttcaggtct 240
gaagacgttg cagatatta ta cttggtgacag actacaggt atctcgttcaac gttggacag 300
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cgttcacag gcagttgtggtat gcaacagat ttcaacctca ctatcagcag tcttcaggtct 240
gaagacgttg cagatatta ta cttggtgacag actacaggt atctcgttcaac gttggacag 300
gggaccaagg tggaataaaa a 321

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cgttcacag gcagttgtggtat gcaacagat ttcaacctca ctatcagcag tcttcaggtct 240
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<400> SEQUENCE: 49

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20  25  30
Tyr Met Asn Trp Val Lys Gln Ser His Gly Lys Gly Leu Glu Trp Ile
35  40  45
Gly Asp Asn Asn Pro Asn Asn Gly Gly Thr Tyr Thr Tyr Asn Gln Lys Phe
50  55  60
Lys Gly Lys Ala Thr Leu Thr Val Asp Lys Ser Ser Ser Thr Ala Tyr
65  70  75  80
Met Glu Leu Arg Ser Leu Thr Ser Glu Asp Ser Ala Val Tyr Cys
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Ala Arg Gly Lys Tyr Gly Thr Ser Tyr Gly Trp Tyr Phe Asp Val
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Trp Gly Thr Gly Thr Thr Val Thr Val Val Ser Ser
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Tyr Asp Ala Thr Val Leu Ala Asp Gly Val Pro Ser Arg Phe Ser Gly
50  55  60
Ser Gly Ser Gly Thr Gln Tyr Ser Leu Lys Ile Asn Ser Leu Gln Ser
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Thr Phe Gly Gly Gly Thr Lys Leu Glu Ile Lys
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<400> SEQUENCE: 52

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We claim:

1. A deimmunized antibody or antigen binding fragment thereof that binds amino acids 1-537 of SEQ ID NO:53, comprising a heavy chain variable region and a light chain variable region, wherein the heavy chain variable region comprises the amino acid sequence of SEQ ID NO:14; and the light chain variable region comprises the amino acid sequence of SEQ ID NO:18.

2. The deimmunized antibody or antigen binding fragment thereof according to claim 1 with similar or greater binding affinity to amino acids 1-537 of SEQ ID NO:53 than a mouse monoclonal antibody produced from the hybridoma ATCC#PTA-6214.

3. The deimmunized antibody or antigen binding fragment thereof according to claim 1, wherein the deimmunized antibody or antigen binding fragment thereof is conjugated to a cytotoxic agent.

4. A pharmaceutical composition comprising the deimmunized antibody or antigen binding fragment thereof according to claim 1.

5. A deimmunized antibody or antigen binding fragment thereof that binds amino acids 1-537 of SEQ ID NO:53, comprising a heavy chain variable region and a light chain variable region, wherein the heavy chain variable region comprises the amino acid sequence of SEQ ID NO:3 and the light chain variable region comprises the amino acid sequence of SEQ ID NO:8.

6. The deimmunized antibody or antigen binding fragment thereof according to claim 5 with similar or greater binding affinity to amino acids 1-537 of SEQ ID NO:53 than a mouse monoclonal antibody produced from the hybridoma ATCC#PTA-11338.

7. The deimmunized antibody or antigen binding fragment thereof according to claim 5, wherein the deimmunized antibody or antigen binding fragment thereof is conjugated to a cytotoxic agent.

8. A pharmaceutical composition comprising the deimmunized antibody or antigen binding fragment thereof according to claim 5.